Stroke Imaging Utilization According to Age and Severity during the COVID-19 Pandemic

Manuscript Type: Research Letter

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SUMMARY STATEMENT

Stroke imaging utilization decreased early in the pandemic, particularly for less severe strokes, but later recovered; there was no meaningful change in the age of imaged patients during the pandemic.

ABBREVIATIONS

AIS = acute ischemic stroke, CTP = CT perfusion
INTRODUCTION

There was a profound decrease in acute ischemic stroke (AIS) evaluations across the United States during the early Covid-19 pandemic (1). This decrease was attributed to stay-at-home measures that were lifted for the later “reopening” period (2). Here, we report trends in nationwide stroke imaging utilization, patient demographics, and imaging characteristics in the early pandemic and reopening periods.

MATERIALS AND METHODS

This unfunded, HIPAA-compliant study was exempted from review by our institutional review board. iSchemaView, Inc. provided study data but was otherwise not involved.

CTP data prospectively acquired at over 800 U.S. hospitals between January 1, 2019 and October 31, 2020 and processed with RAPID (iSchemaView, Inc., Menlo Park, CA) were entered into a de-identified, de-duplicated database. Counts of daily unique patients were generated from this database using imaging timestamps. Counts were subdivided by age, gender, and CTP findings and normalized by the number of active, RAPID-connected hospitals. Cases with missing or mislabeled data were retained. Patients ≤50 years were classified as young (3). CTP was classified as positive if hypoperfusion volume or estimated ischemic core volume was non-zero, and as substantial penumbra if it met the DEFUSE 3 target mismatch profile (4).

Counts were grouped into epochs. The pre-pandemic epoch was January 5, 2020 to February 29, 2020, as counts from this period were similar to an earlier baseline. The early-pandemic epoch was March 26, 2020 to April 8, 2020, corresponding to nadir of the two-week moving average of daily counts. The reopening epoch was June 9, 2020 to October 26, 2020, the earliest period with
no active statewide stay-at-home orders. Epochs were defined in 7-day multiples to exclude weekend effects.

Data are reported as point estimates and 95% confidence intervals. Confidence intervals were determined using a percentile bootstrap and were not adjusted for multiplicity. Analyses were performed in R (version 4.0.2).

RESULTS
The per-site daily volume of CTP, positive CTP, and CTP with substantial penumbra in the early-pandemic period was 37.0% (34.7%, 39.3%), 29.7% (26.1%, 33.1%), and 26.3% (20.7%, 31.5%) lower, respectively, than the pre-pandemic baseline. Following this nadir, imaging volume recovered over 10 weeks (Figure). The per-site daily volume of CTP, positive CTP, and CTP with substantial penumbra during the reopening period was 5.1% (2.9%, 7.3%), 7.8% (5.5%, 10.0%), and 5.3% (1.4%, 8.9%) lower, respectively, than the pre-pandemic baseline.

The fraction of patients with positive CTP or substantial penumbra transiently increased during the early-pandemic phase, then returned to near pre-pandemic levels in the reopening phase (Table). In contrast, there were minimal changes in the fraction of patients that were young or female.

DISCUSSION
Reports from the early pandemic described an association between Covid-19 and AIS (5, 6) and a dramatic increase in large vessel stroke in young patients (3). National data from this period
indicated a nearly 40% decrease in stroke imaging attributed to stay-at-home orders and reluctance to seek care (1).

The current study extends these findings into the reopening period, when stay-at-home measures were lifted yet national Covid-19 prevalence was higher. Our data revealed that imaging volumes recovered from their nadir to near-normal levels over 10 weeks. Modest shifts toward CTP positivity and substantial penumbra in the early-pandemic period were transient. The reversal of these trends is further evidence that early changes primarily reflected social effects. There were no meaningful changes in age or gender profile during the pandemic.

Limitations to this analysis are that CTP is used more commonly for evaluation of severe AIS and that community hospitals are underrepresented. Nevertheless, this report demonstrates the recovery of stroke imaging volume after the early pandemic and the stability of demographic characteristics previously thought to be affected by Covid-19.
ACKNOWLEDGEMENTS

The authors thank iSchemaView for providing study data. iSchemaView was not involved in any other aspect of the study.

A.P.K. serves as an advisory board member and consultant to iSchemaView. G.W.A. is co-founder of and consultant to iSchemaView. M.S.G. and S.H. have no relevant disclosures.
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**Figure.** Daily patients per site undergoing CTP in the United States. Solid line corresponds to 1-week moving average. Shaded regions denote pre-pandemic (blue), early-pandemic (yellow), and reopening (green) intervals.
**TABLE**

*Table.* Patients undergoing brain CTP in the United States. Within epochs, numbers in bold represent daily unique patients per site with the corresponding imaging characteristics, while directly beneath numbers not in bold indicate the proportion of those patients with the corresponding characteristics. Between epochs, numbers represent the ratios of daily unique patients per site in each subgroup between epochs. All data reported as mean (95% CI).

|                      | Within epochs | Between epochs |                  |                  |
|----------------------|---------------|----------------|------------------|------------------|
|                      | Pre-pandemic  | Early-pandemic | Reopening        | Early-pandemic vs pre-pandemic |
|                      | (n=28,131)    | (n=4,595)      | (n=71,013)       | Reopening vs pre-pandemic |
| All CTP              | 0.740 (0.725, 0.755) | 0.466 (0.452, 0.479) | 0.702 (0.694, 0.710) | 63.0% (60.7%, 65.3%) |
| Young (≤50 years)    | 15.1% (14.6, 15.6) | 13.4% (12.5, 14.3) | 15.6% (15.3, 15.9) | 88.7% (82.3, 95.4) |
| Female               | 51.1% (50.5, 51.6) | 49.5% (48.4, 50.4) | 49.9% (49.5, 50.3) | 96.9% (94.5, 99.0) |
| CTP positive         | 49.4% (48.7, 50.0) | 55.0% (53.2, 56.7) | 48.0% (47.6, 48.4) | 111.5% (107.6, 115.2) |
| Substantial penumbra | 29.5% (28.8, 30.1) | 33.9% (32.3, 35.6) | 29.0% (28.7, 29.4) | 115% (109.2, 121.5) |
|                      | 0.365 (0.358, 0.373) | 0.257 (0.245, 0.269) | 0.337 (0.332, 0.341) | 70.3% (66.9%, 73.9%) |
| Positive CTP         |                |                |                  |                  |
| Young (≤50 years)    | 12.1% (11.5, 12.8) | 11.3% (10.1, 12.6) | 12.4% (12.0, 12.8) | 93.6% (81.9, 105.6) |
| Female               | 45.7% (44.9, 46.4) | 46.3% (45.0, 47.8) | 44.2% (43.7, 44.7) | 101.5% (98.1, 105.1) |
| Substantial penumbra | 59.6% (58.8, 60.5) | 61.6% (59.7, 63.6) | 60.5% (60.1, 61.0) | 103.4% (99.8, 107.0) |
| Substantial penumbra | 0.215 (0.207, 0.223) | 0.159 (0.149, 0.169) | 0.204 (0.201, 0.207) | 73.7% (68.5%, 79.3%) |
|                      |                |                |                  |                  |
| Young (≤50 years)    | 11.6% (10.8, 12.4) | 11.6% (9.5, 13.7) | 11.6% (11.2, 12.1) | 100.3% (81.3, 120.5) |
| Female               | 43.4% (42.3, 44.4) | 44.2% (41.8, 46.6) | 42.7% (42.0, 43.4) | 101.8% (95.8, 108.2) |

CTP = CT perfusion.