Stochastic Methods Can Resolve the Dilemma of Emergency Stroke Transport

Daniel A. Paydarfar[1,2], David Paydarfar[2,3], Peter J. Mucha[1], Joshua Chang[2,3,4]

1. Carolina Center for Interdisciplinary Applied Mathematics, Department of Mathematics, The University of North Carolina at Chapel Hill
2. Department of Neurology, Dell Medical School, The University of Texas at Austin
3. Oden Institute for Computational Engineering and Sciences, The University of Texas at Austin
4. Department of Population Health, Dell Medical School, The University of Texas at Austin

Introduction: Drip and Ship (DNS) and Mothership (MS) are well-known emergency transport strategies in acute stroke care, but the criteria for choosing between the two is widely debated. Existing models define time-dependent outcomes but cannot resolve this debate with statistical significance because the independent variables are deterministic. We propose a novel stochastic framework that quantifies statistical significance between DNS and MS in a network of primary and comprehensive stroke centers.

Methods: We represented the physiology of ischemic core growth as a stochastic first-order differential equation, enabling infarct volume at time of reperfusion to be calculated and mapped to 90-day mRS. Using Texas as a case study, we configured the state's stroke network within 15,811 geographic blocks as defined by census data. For each block, we ran Monte Carlo simulations to generate Beta distributions of large- and small-vessel infarct volumes, which were then translated into cumulative distribution functions of mRS. A two-sample Kolmogorov-Smirnov test for significance, and Cohen's d effect size statistic for practical significance were computed between each DNS and MS pair. Stable effect sizes were assured by sampling ≥5,000 total infarct volumes for each block. All model parameters were established from large cohort studies or trials.

Results: Of the 13,113 blocks where the primary stroke center is the closest hospital from origin, DNS produces significantly better stroke outcomes than MS in 79.0% (0.3% SEM; $P < 0.05$; $0.2 < d < 0.5$). For the subset of patients with large-vessel strokes, MS produces significantly better outcomes in 44.6% of blocks (1.3% SEM; $P < 0.05$; $0.4 < d < 0.85$).

Conclusion: Stochastic methods enable the use of clinically relevant metrics for comparative significance of DNS and MS in a geographic region. This formalism, which has not been incorporated in previous models, can be further generalized beyond stochastic infarct volumes if sufficiently large datasets become available. For example, the kinetic growth model can integrate the statistical distributions of times (pre-hospital and hospital) leading up to intervention, and patient attributes that affect outcomes, such as the degree of collateral flow and comorbidities.

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