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Original Article

The Scope and Impact of a Novel, Urban, Rapid Patient Interhospital Transfer System to Improve Neuroemergent Care: The Design and Development of the Neuroemergency Transfer Program

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Abstract

Background: Access to neuroemergent care in the United States represents a significant public health concern, with limited neurosurgery and/or neurocritical care coverage in both rural and urban settings. Inadequate access to neuroemergent providers, even in urban settings, may result in prolonged patient transfer time, associated neurological decline and translate into increased morbidity and mortality.

Methods: A single center retrospective analysis of prospectively collected data of interhospital patient transfers to a neuroscience ICU between 2008-2018 was performed.

Results: 9637 patients were included for analysis. A substantial increase in transfer requests were observed, 610 to 1221 from 2008 to 2018 respectively, with concurrent increase in the number and geographic distribution of referral centers. Ultimately, 7726 (80.2%) patients were discharged home or to outpatient or acute rehabilitation while 1820 (18.9%) were discharged to a long-term acute care facility (LTAC), hospice, or expired during the index admission. The leading diagnoses for transfer were: 1. intracerebral hemorrhage, 2. subarachnoid hemorrhage, 3. ischemic stroke, 4. subdural hematoma and 5. brain tumor. Transfer from an ED or ICU constituted 93.3% of requests. Mean total transfer time between 2012-2018 was < 155 minutes annually (range 128-155 minutes). In 2018, 91.5% of patients had health insurance with 68.7% covered by some form of Medicaid or Medicare.

Conclusions: The ongoing evolution and overall success of the NTP draws chiefly from the designation of an easily accessible central operator to orchestrate transfer, establishing a network of community referral centers and optimization of regional patient transportation - all with the solitary goal of improving patient outcomes.

Keywords: Neurosurgery/economics; Neurosurgery/epidemiology; Neurology/classification; Neurology/economics; Patient transfer; Critical care outcomes

Introduction

Limited access to neurosurgical and neurocritical care in the United States represents a significant and growing public health concern [1,2]. It is well recognized that healthcare infrastructure, investment and training deficiencies limit access to neuroemergent care in rural communities [3-10]. However, a discrepancy in the geographic distribution of patients and neuroemergent providers also exists in urban settings and may translates into increased transfer referrals to tertiary medical centers [1,11]. As a result of increased patient volume, medical liability exposure and essential infrastructure or resources shortfalls, gaps in neurosurgery and/or neurocritical care coverage are increasing [1,12,13]. As such, the importance of providing critically ill neurologic patient's access to pathology-specific expert guided emergent evaluation and treatment underlies the necessity of establishing rapid and reliable interhospital patient transfer systems [1,3,12]. Prior studies have reported mean transfer times for neuroemergent patients between 180 and 300 minutes [1,12,14]. In 2005, Byrne et al. showed a mean transfer time of 310 minutes among 230 transfers to 5 universities in Chicago, IL. Of the 29 patients that experienced a decline in Glasgow Coma Scale score, mean transfer time still exceeded 300 minutes. As a recognized risk factor for progressive neurological decline, prolonged or delayed patient transfer may translate into increased morbidity and mortality [1,3,15-21]. To address the limitations in healthcare providers, as well as inefficient means of patient transfer, we developed a novel interhospital transfer system for the neuroemergent patient.

In the present study, the consistent increase in the annual volume of transfer requests reiterates the need and underlies the importance

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Table 1: Summary of patient characteristics and demographic data from 2012-2018.

	Male		Female		Overall	
Mean Age (yrs)	59.3		61.3		60.3	
Mean ICU LOS (days)	8.9		8.3		8.6	
Sex	3559 (51.10%)		3401 (48.90%)		6960	
	Ed	**ICU**	**Floor**	**Step Down**	**Rehab**	**Other**
Transfer Setting	5526 (79.4%)	967 (13.9%)	271 (3.9%)	56 (0.80%)	119 (1.70%)	21 (0.30%)
	ICH	SAH	IS	SDH	Cranial Tumor	Seizure
Transfer Diagnosis	1635 (23.5%)	1044 (15.0%)	977 (14.0%)	808 (11.6%)	594 (8.5%)	364 (5.2%)

of optimizing the interhospital transfer process. Herein, we describe the development of the Neuroemergency Transfer Program (NTP) and the clinical implications for patient care and associated healthcare outcomes.

Methods

An IRB approved (IRB # 17112802) retrospective analysis of prospectively collected data was performed on patient transfers accepted between 2008-2018 at Rush University Medical Center in Chicago, IL. Patients ≥18 years of age transferred *via* the NTP were eligible for inclusion. No prior screening for the presence, absence of type of healthcare insurance is performed prior to transfer acceptance. Paper documentation was reviewed for relevant clinical information and patient characteristics until the incorporation of an Electronic Healthcare Record (EHR) in 2012. 2019 United States Census Bureau and Illinois Department of Public Health data were evaluated for socioeconomic and demographic data. Characteristics of referral centers were assessed *via* the American Hospital Directory. A review of each referral center's website was performed for determination of the presence or absence of neurosurgical coverage. Statistical analysis of continuous variables was performed using either two-tailed t-test or one-way analysis of variance for determination of statistical significance, with $p < 0.05$ establishing significance (JMP®, Version 14. SAS Institute Inc., Cary, NC, 1989-2019). Raw data is presented using descriptive statistics, continuous variables as means with standard deviation and categorical data as frequencies with percentages.

In the current study, a number of clinical parameters were assessed and include: total transfer time, transfer distance, transfer diagnosis, procedures performed and disposition at discharge. Total transfer time was calculated as the interval between initial acceptance and patient arrival in the Intensive Care Unit (ICU) for the years an EHR was available (2012-2018). In all instances, transfer distance was calculated using the shortest ground route. Categorical determination of transfer diagnosis was based on the visit primary discharge diagnosis indicated in the EHR as this was the most informed and accurate diagnosis. Total and neurosurgical specific procedures and interventions were enumerated from 2008-2018. Neurosurgical specific interventions included: endovascular, bedside and general Operating Room (OR) procedures. Binary determination of patient outcome was undertaken, a "good" clinical outcome included disposition to home, acute or outpatient rehabilitation. A "poor" clinical outcome included discharge to a Long-Term Acute Care facility (LTAC), hospice or death from any causes during the index admission.

Results

In total, 9637 patients were included for analysis with a male predominance of 51.1% and a mean age of 60.3 years (range 18-111 years) (Table 1). Overall, the leading diagnoses for transfer were: intracranial hemorrhage (23.8%), subarachnoid hemorrhage (14.9%), ischemic stroke (14.8%), subdural hematoma (11.5%), intracranial tumor (8.0%), seizure and/or status epilepticus (4.4%),

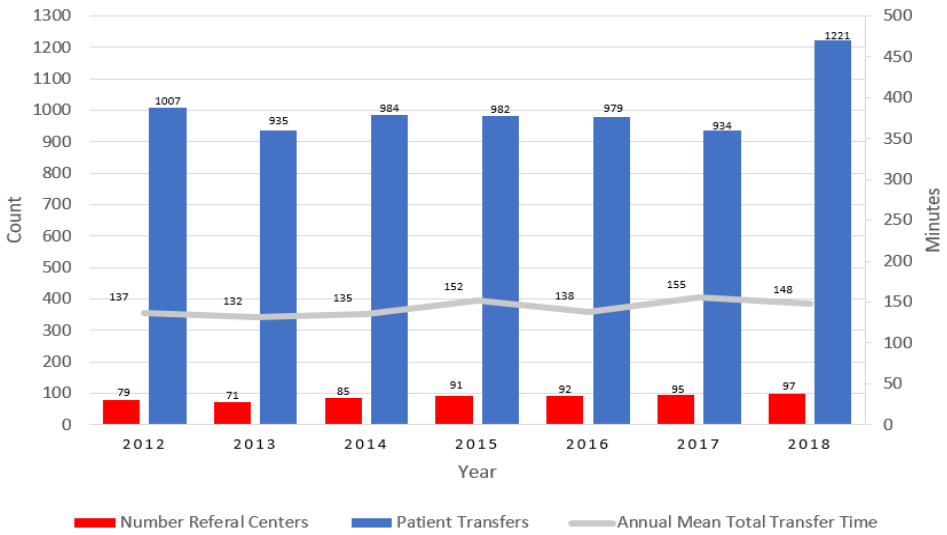

Figure 1: 2012-2018 trend in annual patient transfer volume (blue), number of referral institutions (red) and annual mean transfer time (grey).

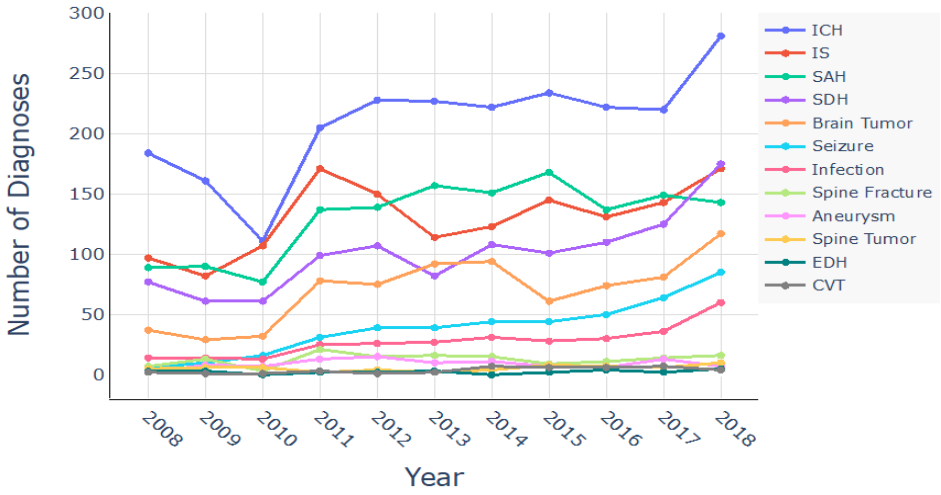

Figure 2: 2008-2018 annual trends in patient diagnosis for transfer.

Table 2: 2018 Transfer diagnosis data stratified by race and ethnicity.

	Race				Ethnicity		
	White	Black	Asian	Not Reported	Hispanic/Latino	Non-Hispanic/Latino	Not Reported
IS	59	61	6	27	14	131	13
SAH	57	42	5	10	15	104	9
SDH	67	63	2	53	33	139	20
ICH	103	162	5	75	38	288	35
EDH	1	2	0	1	1	3	0
CVT	1	3	0	1	0	4	0
Brain Tumor	48	46	1	13	12	106	5
Seizures	65	59	1	26	15	58	4
Infection	7	3	3	8	3	12	5
Spine Fracture	35	15	1	3	2	40	2
Spine Tumor	1	4	1	0	0	2	0
Aneurysm	2	3	0	15	1	6	7
Other	23	21	3	8	6	49	39
Total	469	484	28	240	140	942	139
Overall Total	1221				1221		

central nervous system infection (3.2%), spine fracture (1.5%) and spine tumor (0.6%). A substantial increase in annual transfer volume, from 610 transfers in 2008 to 1221 transfers in 2018 with a concurrent increase in the number of referral centers from 79 institutions in 2012, to 97 institutions in 2018 was observed (Figure 1). Relative trends in transfer diagnoses were maintained from year-to-year with minimal variation (Figure 2) and are stratified by race and ethnicity in Table 2. Annual mean total transfer time was <155 minutes (range 128-155 minutes) with no significant annual variation ($p < 0.05$) (Figure 1). The most frequent categorical distance for transfer was ≥20 miles, followed by 5-9.9 miles, 10-19.9 miles and finally <5 miles.

In total, 7608 procedures were performed, of which 6073 (79.8%) were neurosurgery specific. In 2018, the most common neurosurgical intervention was a diagnostic or interventional angiogram (29.8% of total), bedside placement of an external ventricular drain or lumbar puncture (24.2%), craniotomy for tumor resection (18.1%) and spinal surgery (4.3%). Overall, 391 (4.1%) patients underwent simultaneous tracheostomy and Percutaneous Gastrostomy Tube (PEG) placement, 528 (5.5%) underwent a PEG alone and 63 (0.7%) underwent a tracheostomy alone. Binary determination of clinical outcome was assessed by disposition from the hospital during the index admission. Overall, 7726 (80.2%) and 1820 (18.9%) patients were discharged with a "good" vs. "poor" clinical outcome, respectively (Figure 3). The remaining 0.9% of patients left against medical advice.

Features of referral centers and patterns of patient referral were evaluated. The majority of patients (57.9%) were transferred from institutions with ≤250 beds (range 25-933 beds). In 2018, 52 of the 97 referral institutions did not have neurosurgical coverage, representing 815 (66.7%) transfers. On average, institutions with neurosurgery were larger (270 beds) than institutions without neurosurgery (220

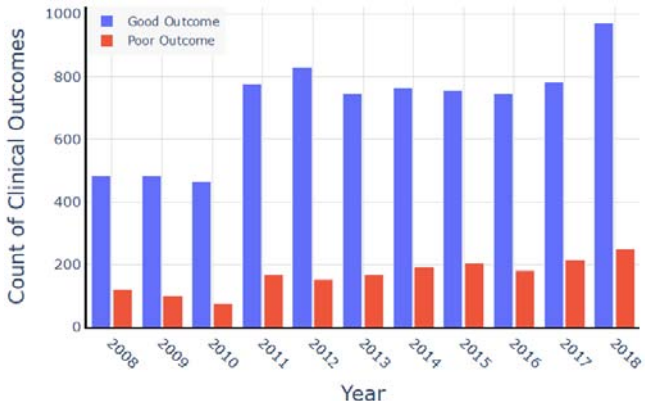

Figure 3: 2008-2018 trend in clinical outcomes by disposition from index hospital admission.

beds). Greater than 90% of all transfer requests were from Emergency Departments (ED) or an ICU. Relative frequencies in the clinical setting of transfer initiation did not vary throughout the study.

Of the 1221 patients transferred 2018, 1117 (91.5%) had health insurance. Of these 1117, 464 patients (41.5%) were covered exclusively by Medicare or Medicaid and an additional 304 patients (27.2%) were covered by a Medicare replacement or Medicaid HMO plan. Of the 104 patients (8.5%) without health insurance, 12 (11.5%) received charity care.

To better understand the socioeconomic landscape of this patient population, median household income was calculated using the patient's home zip code. Overall average median household income for all patients transferred in 2018 was $57,447 (range $18,504-$183,843). Subgroup analysis showed those with Medicaid had an average median household income of $50,263.97 *vs.* $59,500.51 for those with Medicare.

Discussion

We present the largest case series of neuroemergent patient transfers to a single institution over an 11-year period. We describe the impetus, design and development of a new, rapid and high-volume interhospital patient transfer system. Initially, we sought to better understand the discrepancy in the distribution of neuroemergent patients and limitations in neurosurgery and neurocritical care coverage that exists in Chicago and then to develop a streamlined and expeditious process to bring these critically ill patients to our institution.

Until the adoption of an EHR in 2012, paper documentation was reviewed and limited the granularity of available data. After 2012, interrogation of the EHR was feasible and substantially enhanced the volume of clinical information available.

The impetus to reimagine interhospital patient transfer in an urban setting is based on prior work demonstrating limited access to emergent neurosurgical care exists [1,3-9]. This work also showed that progressive neurological decline may occur in up to 15% of patients awaiting transfer and ultimately, that increased transfer time or delays in critical evaluation and initiation of treatment may translate into worse clinical outcomes [1]. These factors underlie the importance of establishing timely and reliable means of interhospital transfer to facilitate subspecialized clinical care.

A progressive increase in the annual transfer volume as well as the number and geographic distribution of referral centers increased from 2008 to 2018 (Figure 1). In 2012, the first year for which comprehensive patient records exist, 980 transfers from 79 referral institutions were completed, which increased to 1221 transfers from 97 institutions in 2018. Over the same time interval, a positive relationship between the distance of transfer and the volume of transfer requests was observed. In 2012, 412 (42.0%) patient transfers were initiated from institutions less than 10 miles away, which relatively decreased to 443 (36.3%) transfers in 2018. Conversely, the proportion of patients transferred from institutions greater than 20 miles away increased from 402 (41.0%) in 2012 to 590 (48.3%) in 2018. This is likely attributable to the expansions of large healthcare networks and increased competition for patients, but it is also a reflection of the success in outreach and growth of the NTP.

As expected, the vast majority (93.3%) of transfer requests were initiated from either an ED or ICU. From 2012 to 2018, the proportion of direct ICU-to-ICU transfer increased by nearly one-half, from 9.4% to 15.0%. Of note, the majority of ICU-to-ICU transfers in 2018 were from institutions with a historically large volume of ED referrals, suggesting a pervasive institutional pattern to direct transfers *via* the NTP. Over the same time period, the proportion of ED initiated transfers slightly declined from 85.7% in 2012 to 75.6% in 2018. Overall, the number of transfers from floor or step-down units or rehabilitation facilities remained low and unchanged. Chronological trends in transfer requests per day of week were noted. Nearly 60% of transfers occurred from Friday evening to Monday morning, with a predictable decrease in transfer requests from Tuesday to Thursday. This weekly pattern in patient transfer volume was consistently observed throughout the study.

In accord with similar studies [1,12,14], the overall leading diagnoses for all transfers were: intracranial hemorrhage (23.8%), subarachnoid hemorrhage (14.9%), ischemic stroke (14.8%), subdural hematoma (11.5%), intracranial tumor (8.0%), seizure and/or status epilepticus (4.4%), central nervous system infection (3.2%), spine fracture (1.5%) and spine tumor (0.6%). Annual trends in transfer diagnosis are depicted in Figure 2. In total, 7608 procedures were performed from patients transferred *via* the NTP from 2008-2018. As predicted from the frequencies of transfer diagnoses, the most common procedures performed were diagnostic or interventional angiograms (43.0% of all procedures), craniotomy for intracranial tumor resection (22.2%), a categorical designation of 'other' (7.9%) and spine surgery (3.7%). Data from 2018 was more scrupulously reviewed and showed bedside procedures, either placement of an external ventricular drain or lumbar puncture were the second most common intervention (24.2% of total interventions). In general, the additional procedures attributable to patients transferred *via* the NTP constitute about 19.7% of annual neurosurgical cases performed at our institution.

Binary determination of clinical outcome was assessed by disposition from the hospital during the index admission. Patients classified as achieving a "good" clinical outcome were discharged home or to outpatient or acute rehabilitation. Those patients classified

as a "poor" clinical outcome were discharged to a LTAC, hospice or expired from any cause. Overall, 80.2% (annual range 77.6-85.2%) and 18.9% (annual range 14.1-21.1%) achieved a "good" *vs.* "poor" outcome, respectively. The annual proportion of patients achieving each clinical outcome were comparable throughout the study. The residual 0.1% of patients excluded from binary determination left against medical advice.

Overall, total mean transfer time for all patients, regardless of transfer distance or annual transfer volume was 142 minutes (range 132-155 minutes) from 2012 to 2018. A slight increase in mean annual total transfer time was observed from 137 minutes in 2012 to 148 minutes in 2018 with a maximal value of 155 minutes in 2017 (Figure 1). As compared to the mean total transfer time of 310 minutes reported by Byrne et al., we show a statistically significant reduction in the annual mean total transfer time in the years from 2012-2018 (range 132-135 minutes) ($p < 0.01$). The trend in increased mean annual total transfer time is likely attributed to the increased proportion of transfers from more distant institutions as previously described.

The concerted process of interhospital patient transfer involves a complex orchestration of events which we organize in 3 distinct settings of patient care: those occurring at the referral institution, during transport and at the receiving institution. In our experience, the evolution and processes for improvement were many and required a swift response.

Although numerous critical modifications at referral centers occurred, here we describe the most impactful. In the early years of the NTP, the ability to make remote treatment recommendations was not permissible due to medical legal liability. This had substantial clinical implications, as many patients arrived at our institution without any standard of care measures instituted. The resolution of legal issues and the ability to remotely evaluate and make initial treatment recommends represented a major advancement. This was most evident for patients with ICH, the leading diagnosis for transfer which requires urgent reversal of coagulopathy, strict blood pressure management and management of cerebral edema and seizures. Additionally, to improve compliance with time-sensitive clinical recommendations, we provided grassroots clinician education and assistance in reformulating referral institution pharmaceutical formularies.

The designation of a Central Operator, an attending neurosurgeon or neurocritical care specialist made directly available 24/7 *via* single phone number was essential. This enabled a simple, direct and increasingly efficient means to facilitate transfer that bypassed the traditional chain of communication through residents and/or fellows.

Physical transportation of the neuroemergent patient, especially in a dense urban environment with highly variable traffic patterns and frequent inclement weather presented a unique challenge. To serve our growing referral network, an exclusive partnership with a reputable regional medical transport company capable of rapid and reliable critical care ground and/or air transport was established. The ability to rapidly and reliably dispatch transport across an ever-expanding geographical region was crucial in minimizing total transfer time.

Several important modifications were necessary at our institution to foster the highest level of clinical care. A new ICU was constructed that expanded the dedicated neurocritical care capacity from 17 to 28 beds with an incorporated computed tomography scanner to facilitate prompt and reliable access to essential imaging. To support the increased bed capacity, a multidisciplinary complement of neurologists, neurosurgeons, anesthesiologists, physiatrists as well as ancillary allied clinical staff were recruited and trained. Upon patient arrival, processes for emergent evaluation, acquisition of labs and studies as well as evidence-based protocols and algorithms for triage were designed and implemented. Processes for activation of the OR and neurospecific staff and equipment were implemented to provide consistent access for cranial, spinal or vascular surgery within 30 minutes of activation.

All patients deemed neuroemergent and appropriate for the NTP are accepted regardless of health insurance status. In 2018, 1117 (91.5%) of patients had some form of healthcare insurance. Of these 1117 patients, 769 (68.8%) were covered by some form of Medicare or Medicaid. 462 patients were covered exclusively by Medicare or Medicaid, the remaining 307 patients had supplemental Medicare or an HMO Medicaid plan. Of the 104 patients without healthcare insurance, 11.5% received charity care. To better understand the public health needs of this patient population, the 2018 data was reviewed in depth. In 2018, overall median household income for a family of 4 in Chicago was calculated at $57,238 [22]. Of the 1221 patients transferred in 2018, 1164 (95.3%) had a home zip code on file used to calculate median household income. Of these 1164 patients, 685 (58.8%) resided in zip codes with an average median household income less than the overall Chicago average (range $20,991-183,500). Conversely, 63 patients (5.4%) resided in zip codes with an average median household income greater than $100,000 annually. Clearly, the epidemiological implications and public health service provided by this transfer program are far reaching.

Taken together, means for process improvement were stratified and evaluated across all settings of the interhospital patient transfer process. Solutions directed at each individual setting were enacted without compromising the reliability or overall transfer time despite the high volume of patients and diversity of institutions. Constant and ongoing evaluation of problems and the rapid development of solutions were necessary across each setting to collectively improve transfer time and clinical outcomes.

Conclusion

We report 11 years of experience and the largest number of published neuroemergent patient transfers to a single institution to date. The present study expands upon prior work that established: limited access to neurosurgical and neurocritical care exists in domestic urban settings, academic medical centers are the most frequent institutions for neurosurgical transfer, and delays in patient transfer may translate into progressive neurological decline and worse clinical outcomes.

The goals of the NTP are multifaceted and aim to provide rapid clinical assessment, expert initial treatment recommendations, and expeditious patient transportation. An initial understanding of the problem at hand - the geographic discrepancy between critically

ill neurologic patients and neuroemergent providers and services - was essential to the formation of community partnerships and the basis of our transfer network. The designation of an easily accessible central operator to initiate transfer as well as provide initial treatment recommendations represented an important advancement. Additionally, partnering with a regional patient transportation service to specifically prioritize and facilitate timely ground or air transport was pivotal in optimizing transfer time.

We report excellent clinical outcomes and an increasing volume of patients transferred *via* the NTP. The ongoing evolution and overall success of the NTP draws from the above characteristics and operates with the singular goal of identifying and transferring the acutely ill neurologic patient as expeditiously as possible for emergent evaluation and rapid treatment to ultimately improve patient outcomes.

Statement of Human and Animal Rights

The present study has been approved by the institutional review board at Rush University Medical Center (IRB #17112802).

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