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Dissecting patterns and predictors of interhospital transfers for patients with brain metastasis

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OBJECTIVE Interhospital transfers in the acute setting may contribute to high cost, patient inconvenience, and delayed treatment. The authors sought to understand patterns and predictors in the transfer of brain metastasis patients after emergency department (ED) encounter.

METHODS The authors analyzed 3037 patients with brain metastasis who presented to the ED in Massachusetts and were included in the Healthcare Cost and Utilization Project State Inpatient Database and State Emergency Department Database in 2018 and 2019.

RESULTS The authors found that 6.9% of brain metastasis patients who presented to the ED were transferred to another facility, either directly or indirectly after admission. The sending EDs were more likely to be nonteaching hospitals without neurosurgery and radiation oncology services ($p < 0.01$). Transferred patients were more likely to present with neurological symptoms compared to those admitted or discharged ($p < 0.01$). Among those transferred, approximately 30% did not undergo a significant procedure after transfer and approximately 10% were discharged within 3 days, in addition to not undergoing significant interventions. In total, 74% of transferred patients were sent to a facility significantly farther (> 3 miles) than the nearest facility with neurosurgery and radiation oncology services. Further distance transfers were not associated with improvements in 30-day readmission rate (OR [95% CI] 0.64 [0.30–1.34] for 15–30 miles; OR [95% CI] 0.73 [0.37–1.46] for > 30 miles), 90-day readmission rate (OR [95% CI] 0.50 [0.18–1.28] for 15–30 miles; OR [95% CI] 0.53 [0.18–1.51] for > 30 miles), and length of stay (OR [95% CI] 1.21 days [0.94–1.29] for both 15–30 miles and > 30 miles) compared to close-distance transfers.

CONCLUSIONS The authors identified a notable proportion of transfers without subsequent significant intervention or appreciable medical management. This may reflect ED physician discomfort with the neurological symptoms of brain metastasis. Many patients were also transferred to hospitals distant from their point of origin and demonstrated no differences in readmission rates and length of stay.

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KEYWORDS brain tumor; brain metastasis; patient transfer; healthcare systems; healthcare delivery; oncology; tumor

Brain metastasis is among the most common malignancies encountered in the central nervous system and affects 30%–40% of patients with solid tumors.[1] It is a disease that requires the cooperation of many specialties, including neurosurgery, radiation oncology, medical oncology, and neurology.[2] Due to complexities of neurological malignancies, interhospital transfer is common for the management of these patients, given that many small community hospitals lack full-time coverage by the subspecialists required for acute management, especially neurosurgeons and radiation oncologists.[3]

However, interhospital transfers contribute to the increasing burden of healthcare costs.[4] A study of neurosurgical interhospital transfers over 2 years at a single ter-

ABBREVIATIONS ED = emergency department; HCUP = Healthcare Cost and Utilization Project; SEDD = State Emergency Department Database; SID = State Inpatient Database.

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tiary institution calculated a cost of $1.46 million in direct transportation alone spent on avoidable transfers.[5] Furthermore, time of clinical handover may result in delays in treatment. In the context of acute management, instances of miscommunication, discontinuity of care, and delays in care may translate into increased patient morbidity or mortality.[6]

Few studies have specifically investigated the dynamic in brain metastasis patients. Given its high incidence rate relative to other brain tumors, it is frequently encountered by both community and academic providers alike. An understanding of when brain metastasis patients can be managed as inpatients locally, and when they require care at a specialized center in the acute setting, may improve not only healthcare cost but also patient convenience and outcomes.

In this study, we performed a retrospective analysis using inpatient and emergency department (ED) data from the Healthcare Cost and Utilization Project (HCUP). We analyzed both patient and hospital factors influencing transfer and sought to understand potential areas of optimization in this system. Our goal was to improve the understanding of acute brain metastasis management and transfer patterns in order to promote safe and efficient triage of care.

Methods

Data Source and Patient Population

We conducted a retrospective observational study that used patients included in the HCUP State Emergency Department Database (SEDD) and the State Inpatient Database (SID) of Massachusetts in 2018 and 2019 as the primary source. The HCUP database is maintained by the Agency for Healthcare Research and Quality. The SEDD captures discharge data on all ED visits that do not result in admission to the hospital where the initial encounter took place.[7] The SID contains the universe of inpatient discharge information, including encounters that began in the ED.[8] We augmented statewide HCUP data with three additional data sources: 1) the 2012 American Hospital Association Annual Survey of Hospitals;[9] 2) hospital ranking data from *US News & World Report*;[10] and 3) individual hospital capabilities data from independent hospital websites.

We limited our analyses to patients with a valid unique patient identifier. This excluded approximately 24% of the total number of records, which were missing an encrypted patient number, date of birth, or gender. Using the patient identifier ("VisitLink") and a timing variable ("DaystoEvent"), we linked records from both SEDD and SID for individual patients and ordered them chronologically. To identify patients with brain metastasis, we extracted patients with ≥ 1 record(s) associated with an ICD-10-CM diagnosis code (C79.31 and C79.32) for secondary neoplasm of the brain and cerebral meninges,[11] and we included only encounters after the first recorded brain metastasis diagnosis to ensure that all patient encounters occurred after brain metastasis diagnosis.

Our study investigated the journeys of brain metastasis patients after their ED encounter. Four routes after ED visits were defined: 1) patients were discharged from the ED; 2) patients were transferred to the inpatient unit of another facility; 3) patients were first admitted to the initial hospital and then subsequently transferred; and 4) patients were admitted to the initial hospital and not subsequently transferred (Fig. 1A). Patients were considered discharged from the ED (i.e., route 1) if their disposition on the ED record was indicated as "routine" or "within hospital clinic referral." Patients were considered transferred from the ED to an inpatient unit (i.e., route 2) if a) the disposition in the initial ED encounter was indicated as "transfer to other facility" and b) there was an inpatient record after the ED record within 1 day. We chose 1 day as the cutoff to distinguish patients who were transferred versus those who had a separate inpatient admission, which is supported by previous studies stating that most transfers occur within 4–6 hours of discharge.[12,13] Patients were characterized as having an inpatient-inpatient transfer (i.e., route 3) if a) there was an inpatient record followed by another inpatient record, wherein the admission date of the second inpatient record fell within 1 day of the discharge date of the first inpatient record, b) the source of the first inpatient record was the ED, and c) the discharge note of the first inpatient record was "transfer to short-term hospital." Lastly, patients were directly admitted at the same hospital (i.e., route 4) if a) it was indicated in the inpatient records that the source of admission was the ED and b) the encounters did not overlap with routes 2 or 3.

Variables of Interest

We analyzed patterns of primary presentation using ICD-10-CM codes from inpatient records, except for patients who were directly discharged from the ED. We chose inpatient records given that they tend to be more robust than ED coding, and because many routes (i.e., ED-inpatient transfer, inpatient-inpatient transfer) did not have ED data. Primary presentations were defined as the first three noncancer ICD-10-CM codes. To understand whether some transfers were potentially avoidable, we investigated whether the transfer resulted in significant intervention and whether the patient was discharged soon after transfer. We characterized significant procedures as any service involving surgery, interventions performed by specialists, radiation therapy, and chemotherapy, and we excluded minor routine procedures (e.g., scans, blood transfusions). Based on the findings of previously published studies, we defined transfers resulting in discharge within 72 hours without intervention as transfers that may have utilized resources inefficiently because no significant medical management was likely administered.[14,15]

Variables of interest included hospital capabilities, teaching status, hospital reputation, hospital commercial network, and patients' prior encounters with the admitting hospital. The capability to treat patients with brain tumors was assessed on the basis of hospital availability of neurosurgery, radiation oncology, and oncology/neuro-oncology providers. These data were obtained through searches of individual hospital websites. The teaching status of each hospital was obtained from the American Hospital Association database, where a teaching hospital is defined as a member of the Council of Teaching Hospitals of

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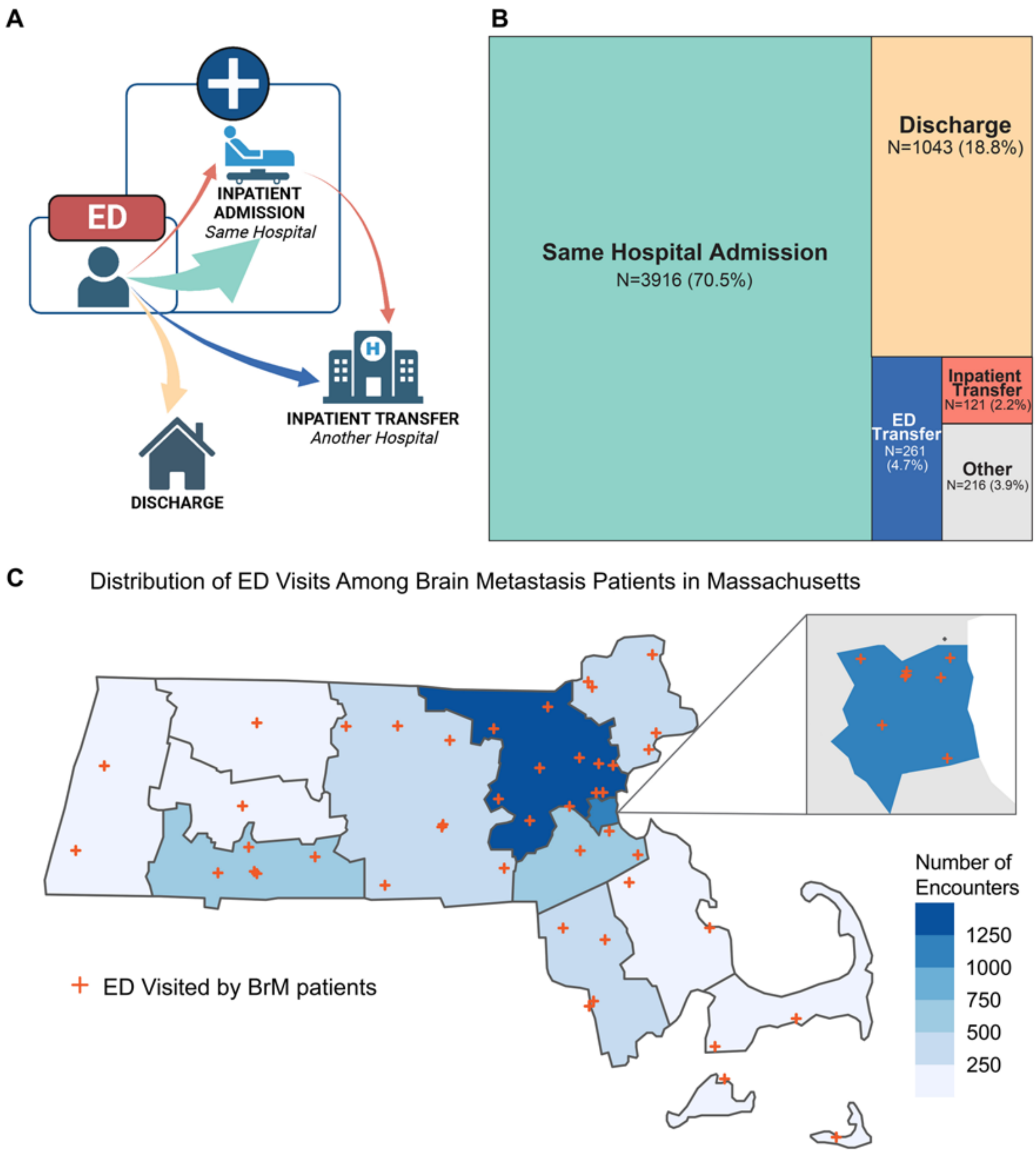

FIG. 1. Overview of the journey of a brain metastasis patient from an encounter in the ED. **A:** The four major paths that brain metastasis patients take after ED presentation are shown: discharged, admitted without subsequent transfer, admitted and then transferred, and transferred directly from the ED. The *widths of the arrows* illustratively represent the proportions of patients in each path. Created with BioRender.com. **B:** Percentages of patients within each major path. The *color scheme* is consistent with the *arrows* shown in panel A. **C:** Geographic distribution of initial ED visits in Massachusetts. The map is divided by counties. The **inset** represents Boston. BrM = brain metastasis.

the Association of American Medical Colleges. Hospital rankings were determined from *US News and World Report*[10] and were ranked ordinally from high to low as ranked nationally, within states, scored, or not scored. To determine whether transfer relationships could have been based on existing hospital ties, we designated each hospital to their respective integrated delivery network, which represents an organization responsible for managing one or more healthcare facilities within a defined geographic area.[16] We determined the patients' prior encounters with a hospital by checking if they had an inpatient or ED record at the hospital where they were admitted (or the recipient hospital, in the case of transfers), even if the record predated their initial diagnosis of brain metastasis.

We calculated two measures of distance:[17] 1) transfer distance, defined as the driving distance between the zip code centroids of the sending and receiving hospitals; and 2) distance to nearest specialized center, defined as

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the driving distance between the zip code centroids of the sending hospital and the closest facility with neurosurgery and radiation oncology services (i.e., specialties that are considered integral to brain tumor management). The driving distance was determined using the Google Maps Distance Matrix Application Programming Interface.

Data Analysis

We applied descriptive statistics to understand differences between the distinct journeys of brain metastasis patients after ED encounters. Normally distributed, nonnormally distributed, and categorical baseline characteristics among the patients who were discharged, transferred, and directly admitted were compared using the t-test, Wilcoxon rank-sum test, and chi-square test, respectively. We performed post hoc pairwise comparisons on significant effects by using the Tukey honest significant difference test and Holm adjustment method for continuous and categorical variables, respectively. To understand the predictors of 30-day and 90-day readmission among transfer patients, we performed univariable and multivariable logistic regression with adjustment for age, Elixhauser Comorbidity Index, intracranial presentation, disposition, and hospital ranking. A two-sided p value of < 0.05 was utilized as the threshold for statistical significance. Analyses were performed using RStudio. This study was approved by the Brigham and Women's Hospital Institutional Review Board and abides by the HCUP Data Use Agreement.

Results

Characteristics of the Initial EDs and Patient Population

We identified 3037 individual patients who presented to the ED after their brain metastasis diagnosis, with 5557 unique ED visits. Most patients (70.5%) were admitted after ED encounter without subsequent transfer, 18.8% were discharged, 4.7% were transferred directly from the ED, and 2.2% were transferred after admission to the initial hospital (Fig. 1B). The ED encounters of brain metastasis patients spanned widely across the entire state of Massachusetts (Fig. 1C), with academic and nonacademic hospitals encountering these patients alike. The transfer of brain metastasis patients spanned 54 hospitals, with 52 sending hospitals, 25 receiving hospitals, and 23 hospitals included in both categories.

Baseline characteristics varied across ED hospitals and patients who were admitted, transferred, or discharged (Fig. 2). Inpatient-inpatient transfer and ED-inpatient transfer patients shared similar characteristics. They were more likely to come from smaller (p < 0.001) and nonteaching (p < 0.001) hospitals compared to patients who were discharged or admitted. Hospitals that directly admitted patients without subsequent transfer were the most likely to have neurosurgery (p < 0.001), radiation oncology (p < 0.001), and neuro-oncology (p < 0.001) services, whereas hospitals that transferred patients from the ED were the least likely to have neurosurgery (p < 0.001) and radiation oncology (p < 0.001) services. There was no significant difference in hospital ownership (profit/nonprofit) between admitting versus transferring hospitals (88% and 85%, respectively; p = 0.107). Interestingly, patients who were directly admitted were more likely to have had prior encounters with the admitted hospital than patients who were transferred (p < 0.001).

We observed fewer significant differences in patient characteristics across transfer patterns. The average ages of the patients who were discharged, admitted without transfer, transferred inpatient-to-inpatient, and transferred ED-to-inpatient were 62.8, 65.8, 65.9, and 63.7 years, respectively, and no significant difference in sex was observed across these groups. Patients who were discharged were less likely to live in metropolitan areas compared with patients who were admitted or transferred (p < 0.05). Of note, those who were admitted and transferred (both from the ED and an inpatient unit) had increased comorbidities compared with those who were discharged. Patients who were directly admitted were more likely to have Medicare/Medicaid as payors than those who were discharged or transferred from the ED (p < 0.05).

Factors Associated With Transfers

A stark difference in hospital-level characteristics was seen between hospitals whose EDs transferred patients and those hospitals receiving transfers (Fig. 3A). Compared to the sending hospital, receiving hospitals were significantly more likely to be teaching hospitals (p < 0.001) and to be staffed with oncologists (p < 0.05), neuro-oncologists (p < 0.001), neurosurgeons (p < 0.001), and radiation oncologists (p < 0.001). Oncology services were present at 100% of the receiving hospitals, and neurosurgery and radiation oncology were available at > 97% of receiving hospitals compared with significantly lower fractions of these specialties at sending hospitals. Receiving hospitals were also more likely to be better ranked at a national or state level and to be designated with nonprofit hospital ownership (95% vs 84%, p < 0.001).

We found that intracranial symptoms were highly enriched among transferred patients (Fig. 3B). Among the top 15 presentations for brain metastasis patients, intracranial conditions and their sequalae accounted for 69% of ED-inpatient transfer patients and 58% of inpatient-inpatient transfer patients versus only 25% of discharged patients and 45% of admitted patients without subsequent transfer (all statistically significantly different, p < 0.001). The prevalence rates of cerebral edema and intracranial hemorrhage were the highest among transferred patients when compared with admitted and discharged patients.

Transfer Efficiency

Transfers from the ED largely took place within the day of presentation (84%), whereas the remaining occurred the subsequent day (range 0–1 day). In comparison, inpatient-inpatient transfers occurred after a median (range) initial hospitalization of 3 (0–21) days (SD 3.35 days) (Fig. 4A).

After transfer to a second facility, over a quarter of patients (28.6% of inpatient-inpatient and 29.5% of ED-inpatient transfers) did not undergo any significant inpatient procedure, as defined as surgery, radiation, chemotherapy, and procedures performed by specialists (e.g., endoscopy-guided interventions) (Fig. 4B). In total, 9.5% of inpatient-inpatient and 12.1% of ED-inpatient transfer

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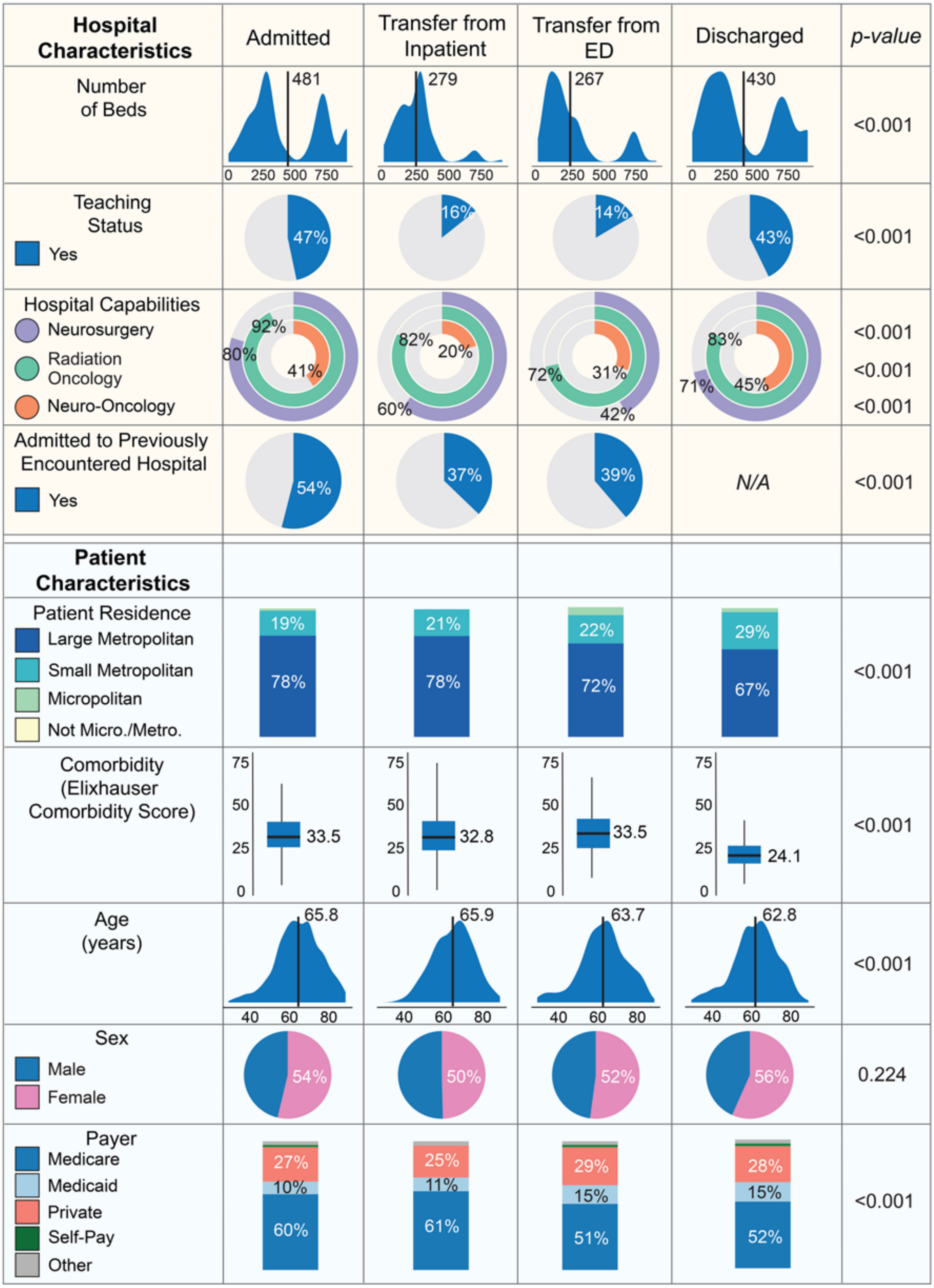

FIG. 2. ED and patient characteristics. The **upper panel** compares the characteristics of the EDs where the patients initially presented, and the **lower panel** compares baseline patient characteristics between dispositions. Mean values are shown for number of beds and age. Elixhauser Comorbidity Score is shown as median (*middle line*), interquartile range (*box*), and minimum and maximum (*whiskers*). Micro./Metro. = micropolitan/metropolitan; N/A = not applicable.

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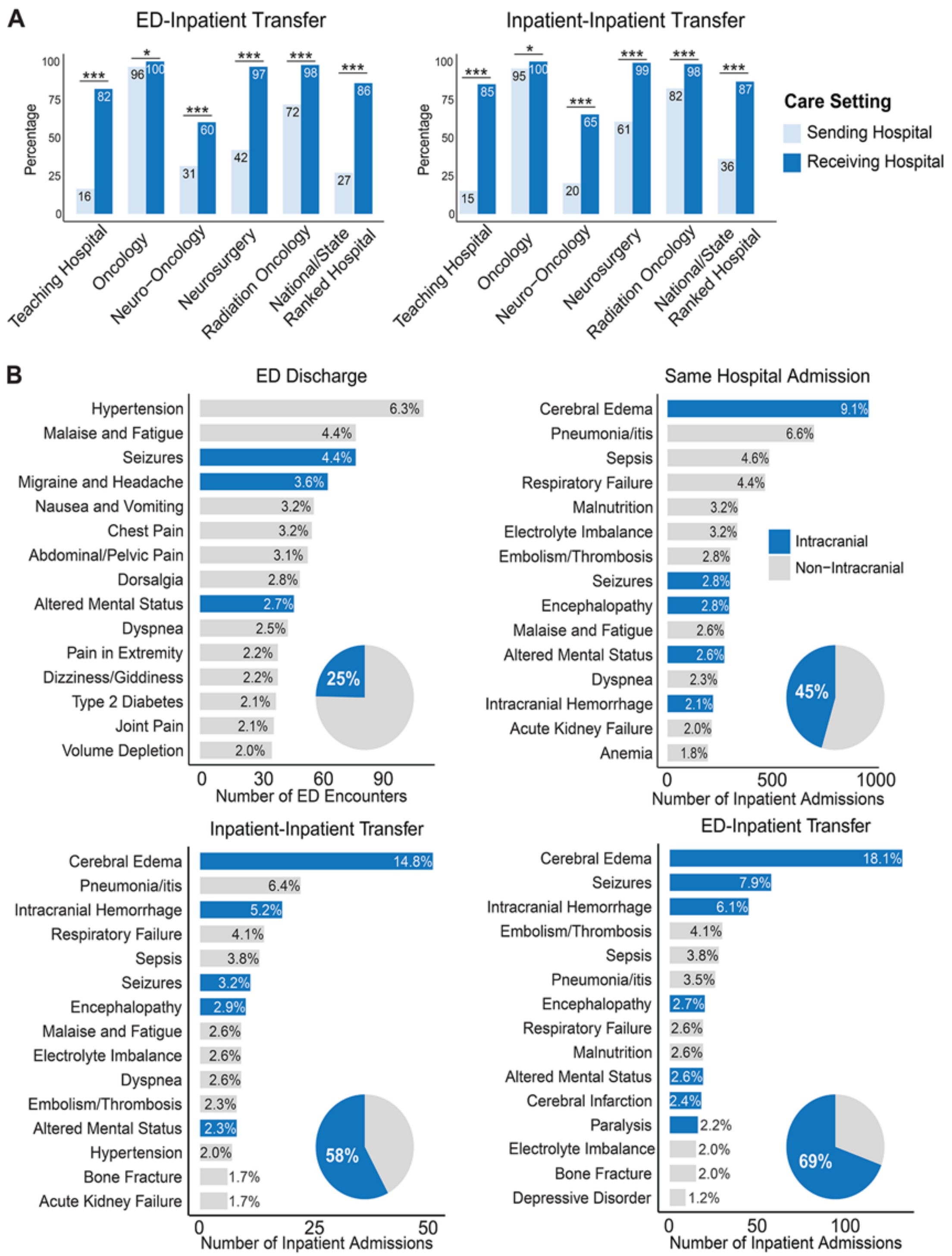

FIG. 3. Factors associated with transfers. **A:** Differences in hospital characteristics between pretransfer (sending) and posttransfer (receiving) hospitals. *p < 0.05; ***p < 0.001. **B:** Top 15 primary clinical presentations among brain metastasis patients, segmented by disposition after ED discharge. The *pie chart on the right side of each chart* represents the proportions of patients with intracranial presentations among all primary presentations. Figure is available in color online only.

patients were discharged < 72 hours after transfer, in addition to not receiving significant procedures. Overall, 19% of patients who were eventually admitted (including transferred patients) underwent a cranial operation. Although presentation with intracranial neurological symptoms resulted in an increase in cranial operations among those directly admitted (32% of patients with intracranial symptoms underwent an intracranial procedure vs 13% of those

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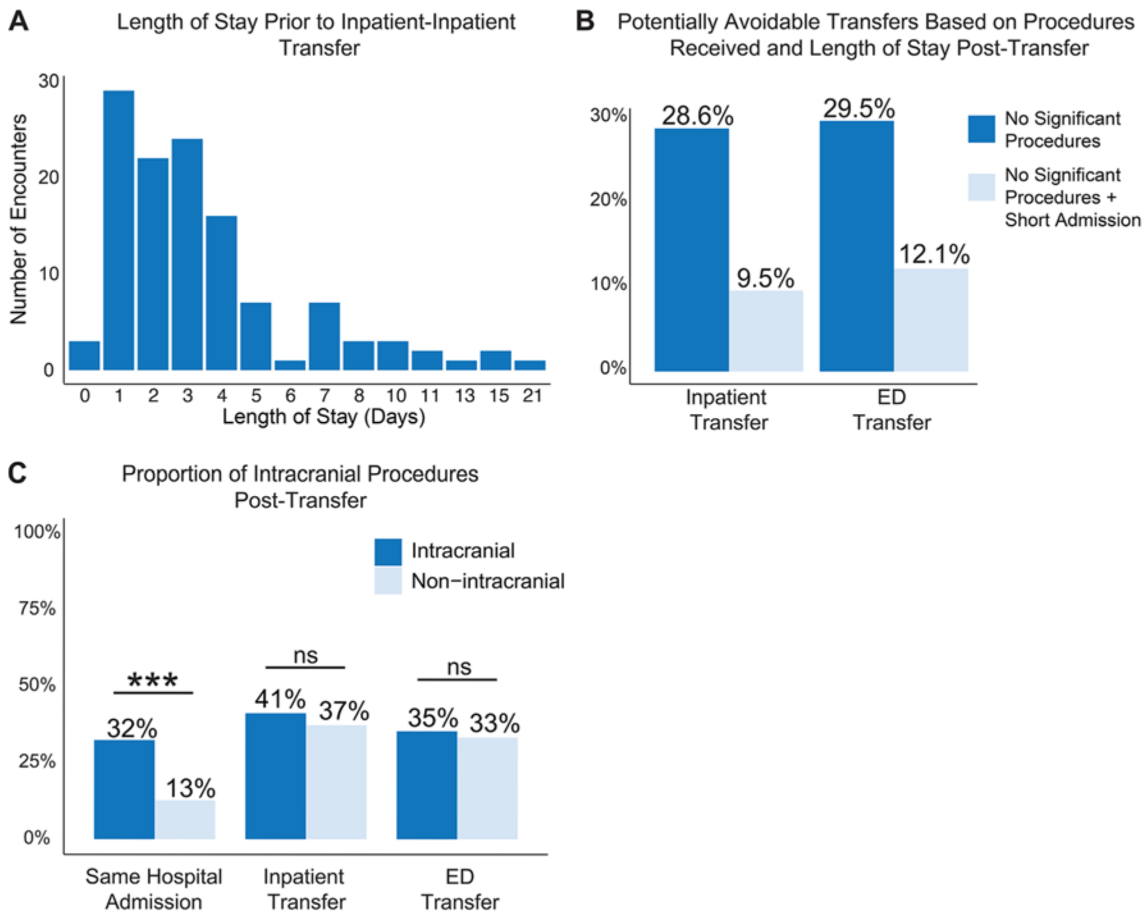

FIG. 4. Areas of optimization in brain metastasis transfers. **A:** Histogram depicting length of inpatient stay prior to transfer. **B:** Proportions of transfers that did not result in surgery, chemotherapy, radiation therapy, or procedures performed by specialists, as well as the proportions of transfers that resulted in early discharge (< 72 hours) in addition to lack of intervention. **C:** Proportions of patients who received cranial operations after transfer, segmented by presence of intracranial symptoms. ***$p < 0.001$. ns = nonsignificant. Figure is available in color online only.

with noncranial symptoms, $p < 0.001$), presentations with neurological symptoms prior to transfer, though enriched, did not increase the likelihood for cranial procedures (41% vs 37% for inpatient-inpatient transfer and 35% vs 33% for ED-inpatient transfer, $p > 0.05$ for both) (Fig. 4C).

We found that patients were often transferred a significant distance beyond the nearest facility with specialized care for brain metastasis (Fig. 5A). Indeed, the median (range) distance of transfer was 21.4 (0.13–105) miles, whereas the median (range) distance to the closest center with radiation and neurosurgery services was only 3.0 (0–54.1) miles. Among all transfers, 30.3% of patients were transferred within 3 miles of the nearest specialized hospital, whereas 74% of patients were transferred beyond 3 miles of the nearest hospital with neurosurgery and radiation oncology services.

We sought to understand the factors that may contribute to distant transfers. We categorized distance transferred into three categories—close (< 15 miles), mid-distant (15–30 miles), and far (> 30 miles)—on the basis of the peaks of the histogram for all distances transferred (Fig. 5B). Essential hospital capabilities such as neurosurgery, radiation oncology, and neuro-oncology did not differ significantly between distances transferred ($p = 0.062$, $p = 0.087$, and $p = 0.083$, respectively). Close (< 15 miles) and distant hospitals (> 30 miles) were more likely to be ranked nationally ($p < 0.001$). Distant hospitals were less likely to be within the same integrated delivery network as the sending hospital ($p < 0.01$). Furthermore, mid-distant and distant hospitals were more likely to be larger hospitals than hospitals at a close transfer distance, with average numbers of beds of 619 and 683, respectively ($p < 0.001$). Hospital ownership did not differ significantly among distances transferred ($p = 0.289$). Interestingly, patients' previous encounters with the recipient hospitals did not differ significantly on the basis of distance transferred ($p = 0.146$).

From a patient perspective, distance transferred was not associated with any significant difference in the Elixhauser Comorbidity Index ($p = 0.295$) or likelihood of neurological presentation ($p = 0.302$). The rates of 30-day and 90-day readmission did not differ significantly among patients transferred over varying distances (30-day readmission rate OR [95% CI] 0.64 [0.30–1.34] for 15–30 miles, OR [95% CI] 0.73 [0.37–1.46] for > 30 miles)

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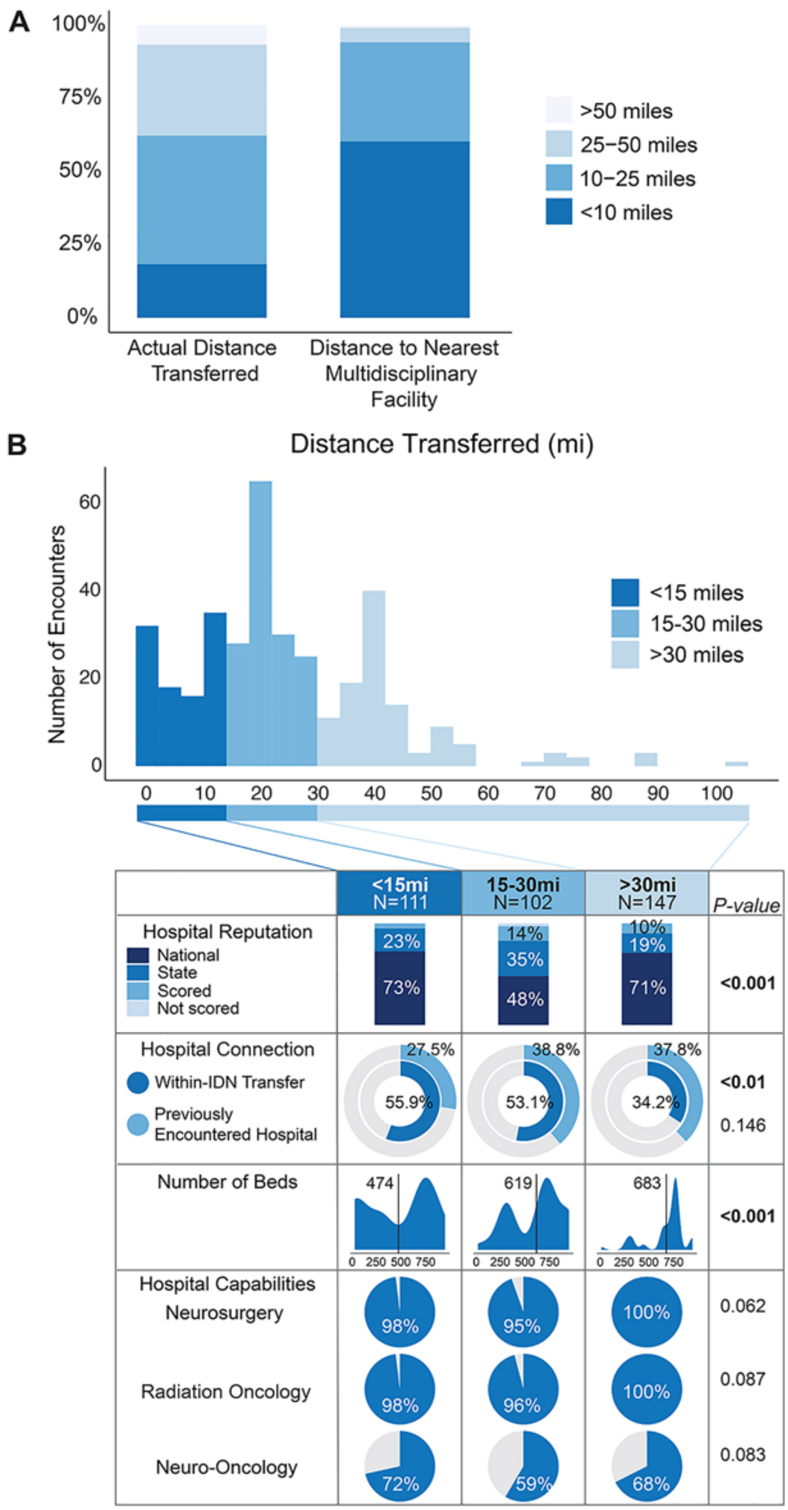

FIG. 5. Total distance transferred. **A:** Comparison of actual distance transferred and distance to nearest facility with neurosurgery and radiation oncology services. **B:** Comparison of hospital characteristics based on extent of total distance transferred. IDN = Integrated Delivery Network. Figure is available in color online only.

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TABLE 1. The 30-day and 90-day readmission rates based on total distance transferred

Total Distance Transferred	30-day Readmission	p Value	90-day Readmission	p Value
<15 miles	Ref		Ref	
15–30 miles	0.64 (0.30–1.34)	0.38	0.50 (0.18–1.28)	0.16
>30 miles	0.73 (0.37–1.46)	0.24	0.53 (0.18–1.51)	0.24

Values are shown as OR (95% CI) unless indicated otherwise.

(90-day readmission rate OR [95% CI] 0.50 [0.18–1.28] for 15–30 miles, OR [95% CI] 0.53 [0.18–1.51] for > 30 miles). The median (range) lengths of stay after transfer were 6.33 (1–30) days, 7.54 (0–49) days, and 7.62 (0–44) days for those transferred within 15 miles, 15–30 miles, and > 30 miles, respectively. Linear regression showed that distance did not predict changes in length of stay (OR [95% CI] 1.21 [0.94–1.29] for 15–30 miles; OR [95% CI] 1.21 [0.94–1.29] for > 30 miles) (Table 1).

Discussion

We sought to understand factors associated with interhospital transfer among brain metastasis patients by tracking patient movement using statewide HCUP data. On average, 6.9% of brain metastasis patients were transferred across facilities after presentation to an ED, either directly from the ED or after initial admission as an inpatient. Compared to the values derived from another study that used the same database, the transfer rate of brain metastasis patients is comparable to the rates of patients with the top 10 most transferred conditions.[18] The relatively high rate of transfer indicates that management of brain metastasis may benefit from many disciplines of specialized care, and targeted analysis could yield opportunities for brain metastasis patients to receive quality care while empowering local hospital networks.

We observed that both hospital-level factors and patient clinical presentation were associated with transfers, whereas patient demographic characteristics and baseline level of health did not appear to be greatly different between the transfer and nontransfer cohorts. At a systems level, transferred patients were more likely to come from smaller nonteaching hospitals with less access to specialists and subsequently flow to larger better-ranked specialized hospitals. Interestingly, a majority of transferred patients did not appear to have been admitted previously to the hospital to which they were transferred, suggesting that a prior therapeutic relationship was not a principal factor in transfer decisions.

Presentation with intracranial conditions and their sequalae was associated with transfer, as neurological complaints, especially cerebral edema and intracranial hemorrhage, were highly enriched among transferred patients. This is consistent with prior research stating that community EDs often transfer patients with intracranial hemorrhage despite mounting evidence that a significant subset is medically unnecessary.[19] Our results revealed that about 1 in 3 transfers did not result in significant intervention after transfer, and 1 in 10 transfers were discharged within 72 hours in addition to not undergoing a significant intervention. Although such transfers could reflect expedited evaluation and discharge by a team experienced in the pathology or familiarity with the patient, it could also represent patients who did not receive additional specialized or extensive medical management and who may have been adequately treated with admission to the initial hospital. Furthermore, although neurological presentations were enriched among transferred patients, these patients were not more likely to receive intracranial procedures than those without neurological presentations, with 30%–40% receiving intracranial procedures after transfer. This is consistent with previous analyses of neurosurgical transfers, where 35%–60% of transfers did not lead to specialized procedures.[6,20] All together, these findings highlight a potential discomfort that ED physicians may have when facing the intracranial sequalae of brain metastasis, as well as an opportunity to strengthen the triage of neurological symptoms in order to improve efficient management of brain metastasis patients.[21]

Patient transfer can incur significant financial costs and inconvenience to patients and their families. To reduce potentially avoidable transfers, several strategies can equip ED physicians and internists with the skills and resources to identify which patients can or cannot be managed inhouse. First, providers can be better trained to assess and manage neurological symptoms more accurately. Previous findings have shown that neurological complaints account for > 5% of all ED visits and consume a disproportionate amount of resources in the ED.[21] Therefore, strengthening the exposure of emergency and internal medicine trainees to neurology or neurosurgery, including rotations or adaptive curricula, may empower more physicians to directly manage certain neurological symptoms rather than to transfer a patient. Second, fortifying access to teleconsultations—and, if relevant, communication with hospitals that have existing relationships with the patient—could help providers make decisions regarding the appropriate management and disposition. Through these consultations, transfer may be deemed unnecessary and admission to the community hospital or outpatient management may be sufficient. In other cases, it may be more appropriate to transfer a patient given their medical need or their extensive existing therapeutic relationship with another facility, which could also reduce duplicate investigations. These solutions may better triage the patients who need transfers, improve cost efficiency, and enhance patient experience.

We also found that brain metastasis patients are often transferred significant distances, with 74% transferred beyond the nearest hospital with neurosurgery and oncology services. Interestingly, transfers to a more distant hospital were less likely to preserve the same integrated delivery

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network as the initial hospital when compared with transfers to a closer hospital. Hospital ranking and size were associated with more distant transfers, although reputation and availability of specialties are not the sole determinants of a hospital's suitability to treat a patient (e.g., patient preference, patient history with a hospital, and hospital capacity are also contributing factors). The extent of patients' prior encounters with the receiving hospitals were in fact similar across transfer distances, indicating that patients traveling farther distances are not more likely to receive care at a facility that knows them well. In our study, we found no significant differences between 30-day and 90-day readmission rates, or in terms of length of stay, across the distances transferred. With that said, short-term readmission data reflect only one facet for measuring patient outcome, and patient experience was not captured in this study. Better understanding of the impact of transfer to closer versus farther facilities may optimize patient convenience and care closer to patient support systems.

A limitation of our study was the inclusion of only one state in the analysis, which—due to differences in the numbers of hospitals, sizes of states, and relationships between facilities—may not reflect the transfer relationships within other states. Second, large administrative databases such as HCUP lack important clinical and case-specific variables, such as patient preferences and primary tumor types, that can also influence transfer decisions. We were able to consider the effect of prior therapeutic relationships on transfer by analyzing whether a patient had prior encounters with a hospital. However, it is worth noting that this variable was unable to capture outpatient encounters, thus underestimating the extent of prior therapeutic relationship. In addition, primary tumor type may influence transfer status, especially among individuals with rare tumors who may be better managed by a specialized team who knows them well and understands the nuances of systemic/trial options. This prompts the need for further studies to investigate the impact of patient-driven and disease-specific factors on transfer decisions. Third, the database used in this study was subject to undercoding of diagnoses and procedures, especially for those not directly linked to hospital reimbursement. Investigations such as CT or MRI may also have been underreported in our database. Indeed, a significant number of records had no procedural coding, which could reflect either lack of intervention or systemic issues in data recording. To address this, we excluded records that had no procedures coded, which reduced the power of the analysis of significant procedures administered.

Conclusions

This study contributes new insight on how brain metastasis patients navigate the healthcare system and sheds light on potential ways the current transfer system could be optimized. We found that the transfer of brain metastasis patients was associated with fewer hospital resources and patient presentation with neurological symptoms, but not necessarily with a prior therapeutic relationship with the receiving hospital. A notable proportion of transfers did not result in specialized intervention or surgical care. Furthermore, we found that patients were often transferred significant distances, frequently beyond the distance to the nearest hospital with subspecialty care, but that distance of transfer was not associated with differences in readmission rates or length of stay. By reducing potentially avoidable transfers and empowering local sites of care through strategies such as provider education and teleconsultation, we can strengthen the healthcare delivery system to optimize resource utilization and patient experience for those patients with brain metastasis.

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Author Contributions

Conception and design: Bi, Tong, Dhand. Acquisition of data: Medeiros, Dhand. Analysis and interpretation of data: all authors. Drafting the article: Bi, Tong. Critically revising the article: Bi, Tong, Moen, Dhand. Reviewed submitted version of manuscript: Bi, Tong, Moen. Approved the final version of the manuscript on behalf of all authors: Bi. Statistical analysis: Tong. Administrative/technical/material support: Bi, Dhand. Study supervision: Bi.

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