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Original Article

Exploring Innovations and Factors to Optimize Adult Neurosurgery Inpatient Flow in Alberta

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ABSTRACT: ***Background:*** Poorly managed inpatient flow can lead to adverse health outcomes, including increased mortality and readmission rates. In neurosurgery, optimizing inpatient flow is crucial to improving patient experience and outcomes, but the factors influencing it are unclear. A preliminary analysis revealed suboptimal average length of stay (ALOS) and expected length of stay (ELOS) rates – key metrics used to assess inpatient flow – across Alberta, Canada. The purpose of this study was to evaluate the current state of inpatient flow in Alberta's neurosurgical care and explore strategies for enhancement. ***Methods:*** This study used mixed methods: a rapid scoping review and a retrospective cohort study. The rapid scoping review synthesized peer-reviewed and gray literature (after a three-stage screening process) to identify factors impacting neurosurgery inpatient flow across jurisdictions. The cohort study analyzed Alberta's adult neurosurgical patient data from 2009 to 2019 to explore how patient- and system-level factors relate to ALOS/ELOS rates. ***Results:*** Nine of the 391 screened articles were included in the review. Three main themes emerged influencing neurosurgery inpatient flow: interdisciplinary care pathways, introducing new roles and identification of risk factors. Building on these themes, patient- and system-level factors impacting ALOS/ELOS were explored. ALOS/ELOS rates varied among the five Alberta Health Services zones, with Rural Zone 1 having the highest and significantly different rate. Age, sex, zone and comorbidities significantly accounted for differences in ALOS/ELOS rates ($p < 0.001$). ***Conclusions:*** Neurosurgery patients in Alberta are experiencing longer hospital stays than expected. Several areas requiring further research have been identified, along with potential strategies to enhance patient care and outcomes.

RÉSUMÉ : Optimisation du roulement des adultes hospitalisés en neurochirurgie, en Alberta : examen de nouvelles façons de faire et de facteurs relatifs au sujet. ***Contexte :*** Les roulements mal planifiés des patients hospitalisés peuvent entraîner des résultats cliniques indésirables, qui se traduisent par une hausse de la mortalité et des taux de réadmission. L'optimisation du roulement des patients hospitalisés est d'une importance capitale en neurochirurgie en vue d'améliorer l'expérience des patients et leur état clinique; toutefois, on ne connaît pas très bien les facteurs qui ont une influence à cet égard. D'après une analyse préliminaire, les taux de durée moyenne des séjours (DMS) à l'hôpital et de durée prévue des séjours (DPS) à l'hôpital – deux indicateurs clés de l'évaluation du roulement des patients hospitalisés – étaient sous-optimaux partout en Alberta, au Canada. L'étude visait donc à évaluer la situation du roulement des patients hospitalisés en cours d'étude aux différents services de neurochirurgie, en Alberta, et à étudier des stratégies d'amélioration. ***Méthode :*** L'étude repose sur deux méthodes : une étude de la portée rapide des écrits scientifiques et une étude rétrospective de cohorte. La première consistait en une synthèse rapide de la documentation évaluée par les pairs et de la documentation parallèle (au bout d'un processus de sélection en 3 étapes), permettant de cerner des facteurs qui influent sur le roulement des patients hospitalisés en neurochirurgie, dans toutes les régions de la province. La seconde portait sur l'analyse de données sur des adultes admis en neurochirurgie, de 2009 à 2019, afin de faire ressortir la manière dont les facteurs relatifs aux patients et ceux relatifs au système sont liés aux taux de DMS et de DPS. ***Résultats :*** Sur 391 articles présélectionnés, 9 ont été retenus dans l'étude de la portée. S'en sont dégagés trois grands sujets qui influent sur le roulement des patients hospitalisés en neurochirurgie, soit les cheminements cliniques interdisciplinaires, l'attribution de nouveaux rôles et l'identification de facteurs de risque. Partant de là, nous avons examiné les facteurs relatifs aux patients et ceux relatifs au système qui influent sur les taux de DMS et de DPS. Ces taux variaient dans les cinq zones de l'Alberta Health Services (AHS), mais ceux de la première zone rurale étaient les plus élevés, en plus d'être sensiblement différents. L'âge, le sexe, la zone et les maladies concomitantes jouaient un rôle important dans les différences de taux de DMS et de DPS ($p < 0{,}001$). ***Conclusion :*** Les patients en neurochirurgie, en Alberta, connaissent des séjours à l'hôpital plus longs que prévu. Plusieurs domaines nécessitant d'être approfondis ont été cernés, de même que des stratégies potentielles d'amélioration des soins aux patients et des résultats cliniques.

Keywords: ALOS/ELOS; cohort; Inpatient flow; neurosurgery; quality improvement; scoping review

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Highlights

- Neurosurgery patients in Alberta are experiencing longer hospital stays than expected.
- There were significant differences in ALOS/ELOS between geographical zones, and patient-level factors account for differences in ALOS/ELOS.
- Three main themes influencing neurosurgery inpatient flow: interdisciplinary care pathways, introducing new roles and identification of risk factors.

Introduction

Healthcare systems worldwide, including those in Sweden, Singapore, the UK and parts of Canada such as Ontario and Alberta, continue to prioritize and work to improve inpatient flow, which remains a significant, consistent health system challenge.[1–5] Inpatient flow is the movement of patients through a healthcare facility, from admission to discharge. Poorly managed inpatient flow can lead to adverse health outcomes, including increased mortality and readmission rates.[6,7] Improving inpatient flow benefits patients, healthcare professionals and the healthcare system. Key benefits include reducing hospital wait times, improving clinical outcomes and patient experiences and saving on overtime and waitlist costs through system efficiency.[8] In neurosurgery, timely and complex interventions highlight the importance of efficient inpatient flow.

Across diverse care settings, many patient-, unit- and system-level factors influence hospital inpatient flow. An emergency department study found that staffing levels, lack of inpatient beds and high patient demands influenced inpatient flow.[9] Red days are days when an acute or community inpatient receives little or no beneficial medical treatment or attention for their condition.[10] They are a metric of inpatient flow, and addressing their causes advances the healthcare system.[10] A study from UK neurosurgical unit ($n = 529$) found that 63% of total red days were attributed to patients awaiting a bed in a local hospital.[10] Other contributing factors included patients with complex discharge needs, those awaiting decisions from non-neurosurgical teams, individuals awaiting social care assessments and care introductions and those awaiting neurosurgery consultant decisions or reviews.[10] The factors influencing inpatient flow in neurosurgery are not as well defined as other areas such as emergency and critical care.

Select studies investigated strategies and interventions to enhance inpatient flow.[6,11–13] For example, in response to high average length of stay (ALOS)/expected length of stay (ELOS), a measure of inpatient flow that compares actual patient stays to expected stays based on factors like age, diagnosis and interventions, a cardiology unit in Canada completed a quality improvement project utilizing Plan-Do-Study-Act to develop a standardized approach for daily rounding, communication and discharge.[11] The study showed improved effectiveness of rounds, enhanced communication and an 11.4% decrease in ALOS/ELOS rates compared to the previous year.[11] The applicability of these findings to neurosurgery inpatient flow is unclear.

Alberta Health Services (AHS) is the single health authority for the Canadian province of Alberta, providing health services to ~ 4.8 million people.[14] Alberta was the first province-wide integrated health system, with zonal variation across five zones (two urban, three rural). Neurosurgical procedures are conducted province-wide, but primarily in two urban centers.[15] Preliminary analysis revealed high ALOS/ELOS rates across Alberta neurosurgery populations, which led AHS to further investigation of the data to understand strategies for improvement.

The purpose of the study was to evaluate the existing state of inpatient flow in Alberta's neurosurgical population and explore potential strategies for improving flow. Our research questions were as follows: (1) What are the interventions/factors that impact inpatient flow for adult neurosurgery patients in different jurisdictions? (2) Are there differences in ALOS/ELOS rates among the five AHS zones (three rural, two urban)? (3) Are ALOS/ELOS rates associated with comorbidity complexity, neurosurgical procedure, age, AHS zone or sex in adult inpatient neurosurgical care in Alberta?

Methods

ALOS/ELOS

ALOS/ELOS is a critical measure of inpatient flow that compares the ALOS to the ELOS. ALOS is the total number of days that a patient spends in the hospital from the date of admission to discharge.[16] ELOS is calculated for typical patients considering the factors for hospitalization, age, comorbidity and complications.[16] Typical patients exclude transfers, deaths, voluntary discharge and extreme ALOS cases, as established by the Canadian Institute for Health Information (CIHI).[17] While ELOS provides an expected duration of stay for patients undergoing specific procedures, it is not a fixed value for every individual and can vary significantly based on patient-specific factors. An ALOS/ELOS ratio <1 indicates that patients are hospitalized for a shorter duration than expected, while a ratio >1 signifies that patients are hospitalized for longer than expected.

Study design

The study employed a convergent parallel mixed-methods design, involving a rapid scoping review and a retrospective cohort study. These methodologies were integrated during data analysis, where review findings contextualized and enriched the cohort analysis.

Phase 1: rapid scoping review

The rapid scoping review of peer-reviewed and gray literature used the PRISMA framework. The review addressed research question 1 to understand the interventions or factors that influence inpatient flow for adult neurosurgery inpatients across jurisdictions.

Search strategy

The rapid scoping review used the PICO framework. The population of interest included adult (>18 years) neurosurgery inpatients. Any interventions or strategies were included, which aimed to improve inpatient flow. Studies with or without comparators were included. The outcomes of interest were the results of interventions or factors aimed at improving inpatient flow. Study eligibility was not limited by study outcomes.

A health librarian executed the search strategy using a comprehensive list of search terms across three databases (CINAHL, EMBASE and MEDLINE). Gray literature was also searched (Supplemental material). The search terms sought the key concepts: inpatient flow, neurosurgical procedures and interventions.

Inclusion and exclusion criteria

All empirical study designs published in peer-reviewed and gray literature were included. Study designs included quantitative

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designs (e.g., randomized-controlled trials and quasi-experimental studies), observational studies (e.g., cohort and case-control studies), mixed-methods studies and qualitative study designs (e.g., ethnography and observation). All studies were published in the English language between 2013 and 2023. Excluded articles included case studies, theses and abstracts.

Data extraction

A three-stage screening and extraction process was employed. First, titles/abstracts were screened using the eligibility criteria. Three independent reviewers screened the first 10 articles to ensure consistent PICO-criteria application and to mitigate biases. Second, full-text screening was completed. Eligibility decisions were recorded using standardized coding on Covidence (2024). Third, data extraction was completed with an *a priori* form (e.g., study information, population, intervention, outcomes) in Microsoft Excel.

Data analysis

A structured narrative synthesis of the extracted data summarized the (a) scope of the interventions, strategies and factors, (b) known impacts of the different types of interventions and (c) quality of the evidence using the Mixed Methods Appraisal Tool (MMAT).[18]

One team member used the MMAT to evaluate study quality, assessing various types (e.g., qualitative descriptive, mixed methods and randomized-controlled studies) during systematic mixed studies' reviews.[18] Lower MMAT scores suggest limitations that affect study validity.[18] Assessment results were recorded, but studies were not excluded based on scores.

Phase 2: retrospective cohort study

A retrospective cohort study addressed research questions 2 and 3 to investigate the potential associations between patient- and unit-level factors and ALOS/ELOS rates in neurosurgical populations in Alberta.

Population

CIHI developed case-mix groups (CMGs) as a system to categorize inpatients discharged from acute care into statistically and clinically similar groups using clinical and administrative data.[19] CMGs broadly fall under major clinical categories (MCCs): broad groupings of diagnoses that classify patients. In neurosurgery, 16 CMGs are grouped into 4 MCCs: MCC 1 (Diseases and Disorders of the Nervous System); MCC 8 (Diseases and Disorders of the Musculoskeletal System and Connective Tissue); MCC 10 (Diseases and Disorders of the Endocrine System, Nutrition and Metabolism); and MCC 19 (Trauma Injury Poison and Toxic Effects of Drugs).[20] The inclusion criteria were identified using CMGs and included patients who had undergone cranial or spinal neurosurgery performed by neurosurgeons, all of whom are based in Edmonton and Calgary but may travel to rural Alberta to provide care (MCCs 1, 8, 10 and 19), adult patients (>18 years) and those treated between 2009 and 2019.

Data collection and analysis

Health system data custodians gathered and de-identified included data from the Discharge Abstract Database, a secondary data source that captures administrative, clinical and demographic information collected during a patient's hospital stay in Alberta and other Canadian provinces and territories.

All statistical analyses were performed using SPSS version 25 (Chicago, IL). Descriptive statistics portrayed demographic characteristics. Analysis of variance (ANOVA) and analysis of covariance (ANCOVA) determined whether there were statistically significant differences in ALOS/ELOS between the AHS zones. The data was positively skewed, as visually interpreted from normal Q-Q plots. As ANOVA is robust to deviations from normality, especially with large sample sizes, and a non-normal distribution does not affect Type 1 error, the data was not transformed.[21] Linear regression examined the individual relationships between predictor variables (age, comorbidity, sex, AHS zone and type of neurosurgical procedure) and ALOS/ELOS. Multiple regression analysis assessed the combined effects between the predictor variables and ALOS/ELOS. The analyses were adjusted for confounding factors: sex, comorbidity, type of neurosurgical procedure and AHS zone. A p value >0.05 was deemed statistically significant.

Results cross-jurisdictional rapid scoping review

Study selection and characteristics

A total of 391 articles were identified from the databases after duplicate removal (Figure 1). After screening 391 titles and abstracts, 348 articles were excluded. The remaining 43 articles underwent full-text screening, with 34 excluded due to the wrong population ($n = 12$), wrong intervention ($n = 13$), wrong setting ($n = 8$) or full-text unavailable ($n = 1$). Nine studies were included in the final review. Two types of study design were identified: retrospective cohort ($n = 8$, 88.9%) and mixed-methods quasi-experimental ($n = 1$, 11.1%). These studies came from five countries, with the highest representation from the USA ($n = 4$; 4.4%), followed by China ($n = 2$; 22.2%), the UK ($n = 1$; 11.1%), Canada ($n = 1$; 11.1%) and Sweden ($n = 1$; 11.1%). Five studies ($n = 5$; 55.6%) were published between 2015 and 2018, and four studies ($n = 4$; 44.4%) were published between 2020 and 2023. The sample sizes varied widely, ranging from 66 to 14,598, with a median sample size of 984. The mean age of participants was 59 years. Across all studies, there was a well-balanced distribution of sex, with an average representation of 47% females.

Study quality

The mean MMAT quality score was 82% ($n = 8$); scores ranged from 80% to 100%. There was a low risk of bias, as the MMAT scores were moderate. The lack of accounting for confounders was the most common reason for the lower scores.

Interventions affecting inpatient flow

Three themes of interventions affecting inpatient flow emerged: interdisciplinary care pathways, identification of risk factors and introducing new roles.

Interdisciplinary care pathways. Four interventions related to interdisciplinary care pathways (Table 1).[10,22–24] These pathways aimed to enhance collaboration among multidisciplinary healthcare professionals involved in the care of cranial and, broadly, neurosurgery patients. These pathways sought to standardize practices, as demonstrated by the Stockholm Stroke Triage System,[22] the patient transfer standardization process,[24] and the SAFER patient bundle.[10] Pathways focused on implementing protocols and algorithms to ensure uniform and effective care delivery. The morning huddle was a unique approach fostering daily team discussions to enhance communication and reduce hospital

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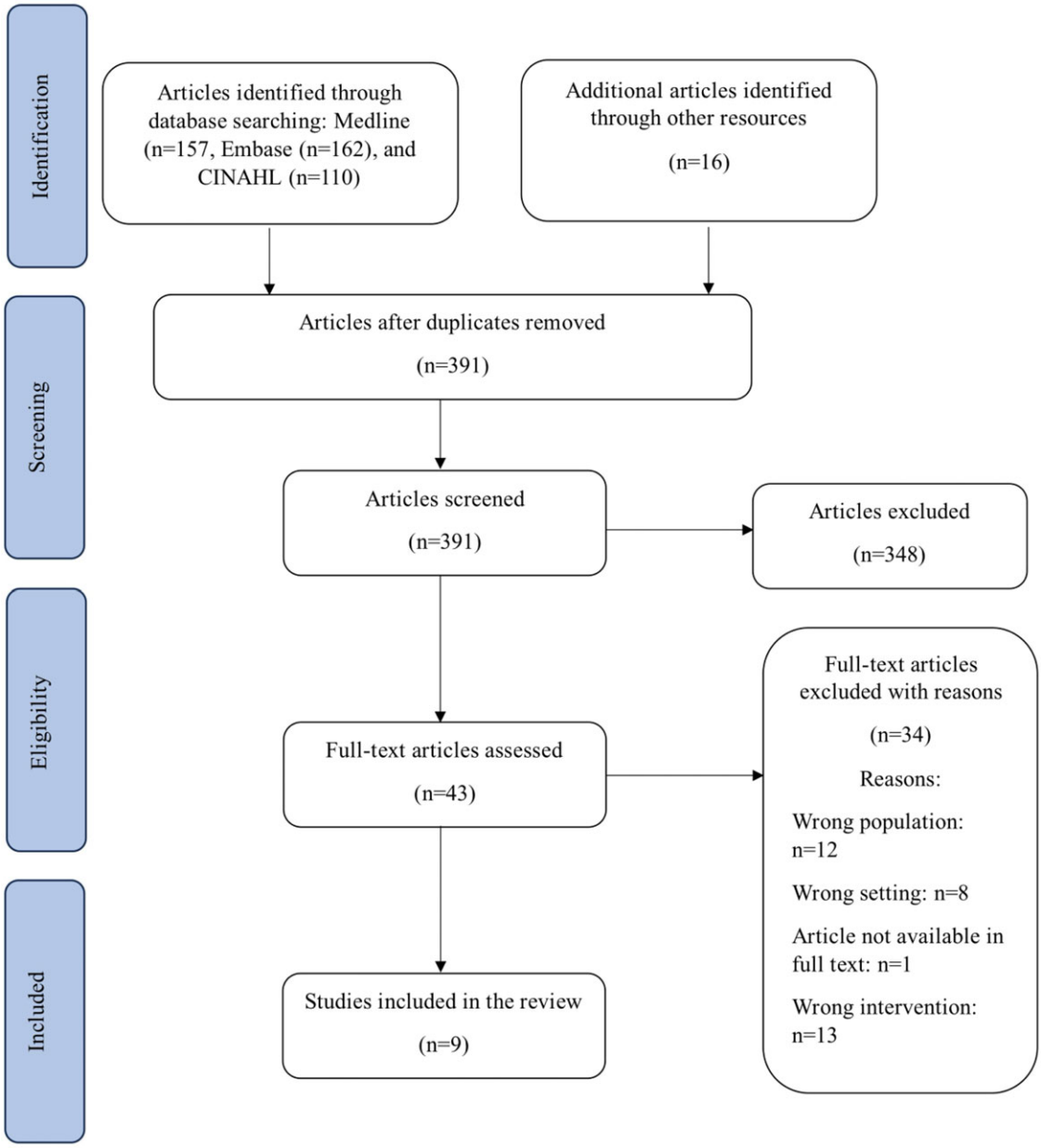

Figure 1. The PRISMA Flow diagram illustrates the identification, screening, eligibility and inclusion process of studies captured by our search strategy.

costs.[23] Pathways focused on different aspects of the care process: efficiency (patient transfer process standardization) and communication (morning huddle). The positive impact of three interdisciplinary care pathways on inpatient flow is evident in various quantitative measures, including reduced ICU days, increased senior reviews and decreased time between successive operations (Table 1).

Identification of risk factors. Three interventions related to the identification of risk factors (Table 2).[25–27] Identification of risk factors aimed to enhance care for spinal and general neurosurgery patients. This included identifying the risk factors associated with patients being discharged to a location other than their home after spinal surgery, analyzing the existing transfer records to identify improvement and identifying predictive markers for readmission. These findings inform predictive factors, particularly measures, for future interventions (e.g., indicators for readmission, discharge and extended transfer times) (Table 2).

Introducing new roles. Two interventions related to introducing new roles (Table 3).[28,29] These roles aimed to expand knowledge of specialized roles in broad neurosurgery settings and enhance care delivery. These roles included physician assistants and advanced practice nurses. Responsibilities, within their scope of practice, included team-based rounding, medication management and bedside procedures.[28,29] The positive impact of both roles on inpatient flow is evident: reduced time for venous thromboembolism prophylaxis ($p = 0.0021$) and decreased length of stay (LOS) ($p = 0.18$) (Table 3).

Alberta-focused retrospective cohort study

Study population

A total of 302,413 patients from 2009 to 2019 met the inclusion criteria. The total sample size may have been an overestimate from

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Table 1. Interdisciplinary care pathways

Intervention description	Setting, population, sample size and study design	Study aim	Results	Impact
Stockholm Stroke Triage System (SSTS) (22). A prehospital algorithm that detects large vessel occlusion stroke patients and gets specialized care faster. The algorithm includes symptom severity assessments and ambulance-to-hospital teleconsultation.	Hospitals in Stockholm, Sweden Individuals who underwent intracerebral hemorrhage neurosurgery ($n = 66$) Retrospective cohort study	To identify patients with large vessel occlusion stroke and transport them immediately to the comprehensive stroke centers, bypassing primary stroke centers.	SSTS led to no significant difference in: • Timing of neurosurgery ($p = 0.98$) • Distribution of functional outcomes ($p = 0.64$) • Death at three months ($p = 0.45$)	No
Weekday 30-minute interdisciplinary neurosurgery morning huddles (23). Every neurosurgery inpatient is discussed by the neurosurgery team at the huddles to improve communication and create a daily care plan.	University of California, Irvine, Medical Center. Neurosurgery patients ($n = 2242$) Retrospective cohort study	To show that huddles can decrease non-essential hospital costs incurred during inpatient hospitalizations and improve patient care and satisfaction.	The huddles led to a decrease in: • Number of intensive care unit days ($p = 0.048$) • $1127.34 per patient in laboratory ($p = 0.011$) and pharmacy costs ($p = 0.002$).	Yes Positive
SAFER patient bundle and Red2Green (10). SAFER streamlines patient care by implementing senior review before midday, discharge expectations with clinical criteria, flow of patients to inpatient wards as soon as possible, early discharge and reviews for patients with prolonged length of stay (LOS). The Red2Green concept ensures that each day a patient spends in the hospital contributes to discharge.	Imperial College Healthcare NHS Trust Neurosurgery patients ($n = 420$) Retrospective cohort study	To evaluate patient flow and identify the number and reasons for red days.	After the implementation of SAFER and Red2Green: • All patients had daily senior reviews before noon. • Multidisciplinary team meetings set expected discharge dates. • 10% of patients had early discharges. Additionally, prolonged LOS occurred in 25% of patients classified as frail ($p < 0.01$)	Yes Positive
Five improvement elements for standardizing the patient transfer process: (1) designing a preoperative preparation item table; (2) following medical record quality standards; (3) using a handover record form; (4) implementing a transfer system for special patients; and (5) communicating between operation room and ward nurses near the end of the operation to facilitate patient transfer (24).	Neurosurgery unit, China. Neurosurgery patients ($n = 2438$) Retrospective cohort study	To decrease the waste of time in transfer; increase the efficiency and qualification rate; decrease handoff errors; eliminate adverse events during patient care handoff from the operating room to the ward; and increase satisfaction.	The transfer process led to: • 10-minute decrease of time between two successive operations ($p < 0.005$) • Increase of the qualification rates for preoperative preparation, medical record preparation, surgical site marking, postoperative instrument and equipment preparation and intraoperative nursing records ($p < 0.005$).	Yes Positive

Note: This table summarizes studies evaluating the impact of interdisciplinary care pathways on inpatient flow. For each study, it includes the intervention description, setting, population, sample size, study design, aims, key results and whether it had an impact on inpatient flow.

the MCC methodology. However, this approach is recognized as a feasible way to find this population in these databases. The mean age of patients was 58 years, and 50.2% of the sample was female (Table 4). Spinal surgery accounted for 69.2% of the surgeries, while cranial surgery accounted for 30.8% (Table 4). A Charlson Comorbidity Index of zero, indicating no comorbidities, was reported in 86.3% of patients (Table 4). Alberta is organized into five AHS geographical zones, with three rural and two urban.[30] Most neurosurgical procedures were performed in the two urban zones with populations > one million (Table 4). The mean ALOS/ELOS rate was 1.41 (Table 5).

Differences in ALOS/ELOS rates across alberta

A one-way Welch ANOVA was conducted to determine if the ALOS/ELOS ratio varied among AHS zones. Participants were classified into five AHS zones based on the site of surgery: Rural Zone 1 ($n = 23{,}575$), Rural Zone 2 ($n = 13{,}699$), Rural Zone 3 ($n = 20{,}024$), Urban Zone 1 ($n = 11{,}4052$) and Urban Zone 2 ($n = 12{,}0614$). The homogeneity of variances was violated, as assessed by Levene's test of homogeneity of variance ($p < 0.001$). The data is presented as mean ± standard deviation. ALOS/ELOS increased from Rural Zone 2 (1.20 ± 0.66) to Urban Zone 2 (1.21 ± 0.75), to Rural Zone 3 (1.23 ± 0.66), to Urban Zone 1 (1.25 ± 0.75) and Rural Zone 1 (1.37 ± 0.71). The results revealed a significant difference in ALOS/ELOS among the five AHS zones, Welch's $F(4, 53{,}824.91) = 278.33$, $p < .0.001$. Post hoc comparisons using Games-Howell revealed statistically significant differences between zones.

An ANCOVA was run to control for covariates. After adjustment for sex, age and comorbidity complexity, there was a statistically significant difference in ALOS/ELOS between the AHS zones, $F(4, 291919) = 165.161$, $p < 0.001$, partial $\eta^2 = 0.002$. Post hoc comparisons using the Bonferroni adjustment revealed statistically significant differences between zones.

Factors associated with ALOS/ELOS rates

For each MCC, linear regression analysis explored the individual relationships between ALOS/ELOS and comorbidity complexity,

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Table 2. Identification of risk factors

Intervention description	Population, setting, sample size and study design	Study aim	Results	Impact
The model identified risk factors for patient discharge to a facility other than home after elective anterior cervical discectomy and fusion (25). The risk factors assessed ranged from patient demographics to preoperative and intraoperative factors.	US hospitals Individuals who underwent elective anterior cervical discectomy and fusion (n = 14,598) Retrospective cohort study	To identify risk factors for non-home patient discharge after elective anterior cervical discectomy and fusion.	Predictive factors in patient discharge to a facility other than home included (p =<0.001): • Age 65+ years • Race • Obesity • Diabetes • Functional status • Operation time >4 hours • Cardiac comorbidity • American Society of Anesthesiology physical status classification class >3.	Yes Positive
The model analyzed interhospital transfer records of neurosurgical patients to identify trends, failures and potential areas for improvement in the transfer process, including efficiency, diagnostic accuracy, triage and resource allocation (26).	Two academic, tertiary care hospitals: Emory University Hospital (EUH) and EUH Midtown Neurosurgery patients (n = 984) Retrospective cohort study	To report the transfer records of a large tertiary care center to identify trends, failures and opportunities to improve interhospital transfer of neurosurgical patients.	• There was no significant relationship between the transfer request location and whether the transfer was accepted or denied (p = 0.92). • The median interval between transfer request and patient arrival was 4 hours 2 minutes, which was a median delay of 3 hours 11 minutes for transfer. • The distance to the referring hospital was positively correlated with mean transfer time (p = 0.007) and mean delay (p = 0.02).	Yes Positive
The model identified predictive markers for readmission of neurosurgical patients who had been previously transferred to an intermediate step-down care facility (27).	Department of Neurosurgery, Tan Tock Seng Hospital in Singapore Neurosurgical patients transferred from a tertiary hospital to an intermediate step-down facility (n = 129) Retrospective cohort study	To report and analyze the factors involved in the readmission of neurosurgical patients over a 2.5-year period and explore possible predictive markers for readmission.	Predictive markers for readmission included. • Higher pretransfer procalcitonin levels (p = 0.037) Ethnicity (p = 0.026).	

Note: This table summarizes studies evaluating the impact of the identification of risk factors on inpatient flow. For each study, it includes the intervention description, setting, population, sample size, study design, aims, key results and whether it had an impact on inpatient flow.

Table 3. Introducing new roles

Intervention description	Population, setting and sample size and study design	Study aim	Results	Impact
Weekday physician assistant (PA) on the neurosurgery unit (28). Their responsibilities were for the general units, intermediate care units and intensive care unit (e.g., inserting intracranial pressure monitoring bolts)	Community-based academic Level 2 trauma facility in the USA. Neurosurgery patients (n = 2777) Retrospective cohort study	To expand knowledge of the effect of PAs and nurse practitioners on cost-effective care in the inpatient academic setting.	The PA led to a decrease: • Time to venous thromboembolism prophylaxis (3216.68–2608.74 [p = 0.0021]). • Hospital length of stay (108.98–97.44 [p = 0.18]).	Yes Positive
Weekday advanced practice nurses (APNs) on the neurosurgery unit (29). Their responsibilities encompass clinical and consulting as well as education, research and leadership components (e.g., facilitating family meetings and ordering and interpreting results).	Inpatient neurosurgery unit at a Canadian Tertiary Care Center Neurosurgery patients (n = 75) Mixed methods quasi-experimental study	To evaluate perceptions of the effectiveness of the implementation of an innovative APN role on an inpatient neurosurgery unit.	The APNs led to: • 202% increase in oral communication between the nursing staff and the APN/medical team (p < 0.001) • 204% increase in communication of the written plan of care (p < 0.001) • 360% increase in learning opportunities for the nursing staff (p < 0.001) • Decrease in the number of patient-related calls (p = 0.031)	Yes Positive

Note: This table summarizes studies evaluating the impact of introducing new roles on inpatient flow. For each study, it includes the intervention description, setting, population, sample size, study design, aims, key results and whether it had an impact on inpatient flow.

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Table 4. Demographics (2009–2019)

Demographic variable	Patients (n = 302,413)
Age admitted (years)	58.1 (19.3)
Sex	
Male	149,984 (49.6%)
Female	152,429 (50.4%)
Primary Surgical Categorization	
Cranial surgery	92,634 (30.6%)
Spinal surgery	209,779 (69.4%)
Charlson Comorbidity Index	
0	259,754 (85.9%)
1	20,138 (6.7%)
2	14,010 (4.6%)
3	2522 (0.8%)
4	772 (0.3%)
5	213 (0.1%)
<5	5004 (0.8%)
AHS Zone	
Rural Zone 1	24,237(8.0%)
Rural Zone 2	13,966 (4.6%)
Rural Zone 3	20,689(6.8%)
Urban Zone 1	118,325 (39.2%)
Urban Zone 2	124,670 (41.3%)
Major Clinical Categories (MCC)	
MCC 10: Diseases and Disorders of the Endocrine System, Nutrition and Metabolism	3643 (1.2%)
MCC 8: Diseases and Disorders of the Musculoskeletal System and Connective Tissue	206,902 (68.4%)
MCC 1: Diseases and Disorders Nervous System	85,803 (28.4%)
MCC 19: Trauma Injuries Poison and Toxic Effect of Drugs	6065 (2.0%)

Note: This table summarizes the patient demographics. Values are presented as means (standard deviation) for continuous variables and counts (percentages) for categorical variables.

Table 5. ALOS/ELOS rates (2009–2019)

Descriptive statistics	Patients from 2009 to 2019 (n = 302,413)
Mean	1.41
Median	1.11
Mode	1.36
Standard deviation	1.41
Variance	1.99
Skewness	11.69
Range	0.00–113.64

Note: This table summarizes descriptive statistics for patient ALOS/ELOS rates. ALOS/ELOS = average length of stay/expected length of stay.

age, sex, AHS zone and neurosurgical procedure. Despite the linear regression results, all variables were included in the final multiple regression models. Researchers argue that while statistical significance is one method, the value of a variable should also be assessed by its regression coefficient.[21] The written results herein only present MCC 8 as an exemplar.

For MCC 8 (limited to spinal surgery), significant relationships were revealed between each predictor variable and ALOS/ELOS. Patient comorbidity complexity ($\beta = 0.036$, $p = <0.001$) and age ($\beta = 0.272$, $p = <0.001$) demonstrated positive correlations with ALOS/ELOS. Patients in Rural Zone 1 ($\beta = 0.14$, $p = <0.001$) and Urban Zone 1 ($\beta = 0.04$, $p = <0.001$) demonstrated higher ALOS/ELOS rates. Urban Zone 2 ($\beta = -0.05$, $p = <0.001$), Rural Zone 3 ($\beta = -0.04$, $p = <0.001$) and Rural Zone 2 ($\beta = -0.73$, $p = <0.001$) demonstrated that patients in these zones tend to have lower ALOS/ELOS rates. Sex demonstrated a negative correlation with ALOS/ELOS ($\beta = -0.107$, $p = <0.001$), indicating that females generally experience higher ALOS/ELOS rates compared to men.

Multiple regression analyses were conducted to explore the combined associations between ALOS/ELOS and sex, age, AHS Zone, comorbidity complexity and neurosurgical procedure for each of the MCCs. For MCC 8, the multiple regression model statistically significantly accounted for the difference in ALOS/ELOS, $F(8, 201737) = 2341.24$, $p < 0.001$, $\Delta R2 = 0.085$ (Table 6). Sex, comorbidity, age, Rural Zone 1, Urban Zone 1 and Urban Zone 2 added statistically significantly to the model ($p < 0.001$). The $\Delta R2$ for the model was 0.085, indicating that 8.5% of the difference in ALOS/ELOS rates was attributed to the statistically significant variables in the model.

MCC 1, MCC 10 and MCC 19 had lower $\Delta R2$ values compared to MCC 8. For all MCCs, sex, comorbidity complexity and age added statistically significantly to the associations, $p < 0.001$. For MCC 1, the multiple regression model statistically significantly accounted for the difference in ALOS/ELOS, $F(8, 81{,}498) = 127.47$, $p < 0.001$, $\Delta R2 = 0.012$. For MCC 10, the model statistically significantly accounted for the difference in ALOS/ELOS, $F(8, 3310) = 21.32$, $p < 0.001$, $\Delta R2 = 0.047$. For MCC 19, the model statistically significantly accounted for the difference in ALOS/ELOS, $F(7, 5854) = 22.49$, $p < 0.001$, $\Delta R2 = 0.025$.

Discussion and Conclusions

Results synthesis

Study findings indicated that neurosurgical patients in Alberta were staying longer in hospitals than expected; there were significant differences in ALOS/ELOS between the geographical Zones; patient-level factors account for differences in ALOS/ELOS.

The results revealed significant differences in ALOS/ELOS rates across the AHS zones. The mean ALOS/ELOS rates for each zone were greater than one, indicating a province-wide need to improve. Rural Zone 1 had the highest mean ALOS/ELOS, suggesting a priority area for further investigation. We speculated that Rural Zone 1 had the highest ALOS/ELOS rates given its rural location and lack of neurosurgery infrastructure and resources, posing challenges in neurosurgery patient treatment and postoperative care. Previous research aligns with this finding, highlighting the discrepancies in access to acute care services for those living in rural versus urban areas.[31] The finding that ALOS/ELOS rates in Urban Zone 2 and Rural Zone 2 were almost equal to one suggests that they are operating relatively effectively, warranting further investigation to share their successful practices with other zones.

The findings revealed that a small portion of the variance in ALOS/ELOS, ranging from 1.2% to 8.5%, was explained by patient-level factors (age, sex and comorbidity complexity) and geographical setting. These findings align with the rapid scoping

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Table 6. Multiple regression results for MCC 8: Disorders and Diseases of the Musculoskeletal System and Connective Tissue

ALOS/ELOS	B	95% CI for B	SE B	β	R^2	ΔR^2	*P*-value
Model							
Constant	0.65	0.59, 0.71	0.03		0.085	0.085	<0.001
Age	0.01	0.01,0.01	0.00	0.26			<0.001
Sex	−0.11	−0.12, −0.11	0.00	−0.08			<0.001
Comorbidity complexity	0.01	0.01,0.02	0.00	0.02			<0.001
Rural Zone 1	0.18	0.13,0.24	0.03	0.08			<0.001
Rural Zone 2	0.03	−0.03,0.09	0.03	0.01			0.263
Rural Zone 3	0.01	−0.05,0.07	0.03	0.00			0.723
Urban Zone 1	0.13	0.07,0.19	0.03	0.09			<0.001
Urban Zone 2	0.09	0.04,0.15	0.03	0.07			0.002

Note: This table summarizes the results of the multiple regression for MCC 8: Disorders and Diseases of the Musculoskeletal System and Connective Tissue. B = unstandardized regression coefficient; CI = confidence interval; SE *B* = standard error of the coefficient; β = standardized coefficient; R^2 = coefficient of determination; ΔR^2 = adjusted coefficient of determination.

review, which found that identifying risk factors is a determinant of inpatient flow. Despite small ΔR2 values, some statistically significant predictors emerged that have practical implications for focusing future healthcare practices. Higher ALOS/ELOS rates were associated with those who were female, had more comorbidities and were older. These findings were consistent with other studies that found that patients who are older and more frail have longer hospital LOS.[31,32]

The cohort findings were complemented by the rapid scoping review, which explored strategies for improving inpatient flow in neurosurgery. The identification of risk factors and subsequent addressing of risk to improve inpatient flow is a consistent finding from various healthcare studies.[27,28] For instance, creating personalized healthcare treatments by integrating patient comorbidities into patient management may reduce hospital length of stay and costs and improve patient outcomes.[35] Consistent with the findings, a UK study corroborates the impact of interdisciplinary care pathways on improved inpatient flow.[36] The Leeds Improvement Method, a structured approach to continuous improvement and quality management, used in the UK, improved inpatient flow in neurosurgical critical care transition of critical care patients to lower levels of care at night and decreased the number of canceled elective cases.[12] Several studies provided further support for the theme of introducing new specialized roles to improve inpatient flow.[6,13] A UK study in a surgical unit assigned a radiologist to assess and report CT scanning, resulting in decreased CT scan and discharge time.[6] The review results have important implications for researchers, healthcare providers and stakeholders, guiding future interventions, education and policies to enhance inpatient flow in neurosurgical care in Alberta.

Limitations

This study had limitations. First, one researcher completed the three-stage rapid scoping review and quality assessment. Second, a limited number of variables were included in the analysis, and we used administrative data, which does not capture self-identification of gender, income or race. Third, the approach used to identify neurosurgery patients using MCCs may have been overly broad and encompassed non-neurosurgery patients (e.g., orthopedic surgery). Finally, the comparison of ALOS/ELOS rates between rural and urban zones may have been misleading due to their differing neurosurgical populations and the additional resources available to support outflow in urban settings.

Future directions

More research is needed to further understand the relationships between ALOS/ELOS and patient-, unit- and system-level factors including investigation of additional factors that may impact ALOS/ELOS rates such as socioeconomic status and staffing levels. To ensure that Alberta neurosurgery patients are accurately represented, future research should use a narrower method for identifying patients, such as case-mix grouping, intervention codes, diagnosis codes (ICD-10) or neurosurgeons conducting the procedure. Additionally, more research is required to determine whether the increased ALOS/ELOS in females is due to gender (contextual) or sex (physiological) factors. A question arises as to whether care delivery in neurosurgery treats patients differently based on their sex or gender. Finally, a deeper analysis of the differences in ALOS/ELOS rates between the rural and urban zones may identify the reasons for variation and specific areas for improvement.

Conclusions

Neurosurgery patients in Alberta are experiencing longer hospital stays than expected. Several areas requiring more research have been identified, along with potential strategies to enhance patient care and health outcomes.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/cjn.2025.10358.

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