A 10-Year Analysis of 3693 Craniotomies during a Transition to Multidisciplinary Teams, Protocols, and Pathways

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ABSTRACT

Introduction: A Cochrane review of teams, protocols, and pathways demonstrated improved care efficiency and outcomes over a traditional model. Little is known about this approach for craniotomy.

Methods: This observational study involved sequential implementation of a multidisciplinary team, protocols, and a craniotomy pathway. Data on 3693 admissions were retrospectively reviewed at a tertiary care neurosurgery center from 2008 to 2017 for the top 6 diagnosis-related group codes. In June 2016, a searchable discharge summary template in the electronic medical record was implemented to capture data regarding quality, efficiency, and outcomes.

Results: Staffing transitioned to a team of neurosurgeons, neurointensivists, neurohospitalists, and midlevel practitioners. Order sets, protocols, and pathways were developed. Quality improvements were observed for craniotomy and cranioplasty surgical site infections, ventriculitis, coagulopathy reversal, and decompressive hemicraniectomy rates for stroke. Case volume increased 73%, yet craniotomy hospital days decreased from 2768 in 2008 to 2599 in 2017 because of reduced length of stay. We accommodated service line growth without hospital expansion or case backlogs. With an average California hospital day rate of $3341, the improved length of stay decreased costs by $14,666,990/y. We also present outcomes data, including craniotomy indications, operative timing, complications, functional outcomes, delays in discharge, and discharge destinations using the craniotomy discharge summary.

Conclusion: Multidisciplinary teams, protocols, and pathways reduced craniotomy complication rates, improved hospital length of stay by 63%, reduced costs, and increased professional collegiality and satisfaction. A searchable craniotomy discharge summary is an important tool for continuous monitoring of quality and efficiency of care.

INTRODUCTION

Under the traditional model for hospital care, an attending physician directly oversees all aspects of care and consults with specialists when needed. However, for certain diagnoses or procedures, care delivery using multidisciplinary teams, protocols, and care pathways may improve outcomes and care efficiency.[1] For this team approach to work, clinicians must first agree on a uniform approach to a specific clinical problem or procedure using evidence-based guidelines and consensus. In the fee-for-service model, individual physicians and physician groups may directly compete for patients and surgical case volume. This competition can be a barrier to developing protocols and pathways. Conflicts and disputes may also arise when care is coordinated between teams of surgeons and nonsurgical physicians. Physicians may resist developing procedures and protocols because of loss of physician autonomy and valid concerns about individual patient variations and personalized medical care. Because transitioning from a traditional care model to a team-oriented model may require considerable effort and time, most reports investigating care pathways have strategically focused on high-volume costly diagnoses such as cardiac disease and joint replacement surgeries.

A 2010 Cochrane review evaluated the effects of clinical pathways on clinical documentation, quality of care such as mortality or patient complications, acute-care length of stay (LOS), and cost of care.[1] The study included 27 reports and 11,398 participants. The authors concluded that pathways were associated with reduced complications, improved clinical documentation, and decreased hospital costs and LOS. We were unable to find publications cited in the Cochrane review regarding craniotomy care, but the review did find favorable results for acute stroke care and complex surgeries such as coronary artery bypass grafting. A few small studies have investigated the feasibility of avoiding intensive care unit (ICU) admissions for craniotomies[2,3] and also same-day surgery for craniotomy.[4]

We present a descriptive study of our transition from 2008 to 2017 to the care of patients undergoing craniotomy using a multidisciplinary team model, protocols, and pathways at Kaiser Permanente (KP) Sacramento Medical Center, a tertiary care neurosurgery center in Sacramento, CA. An important advantage of the KP model of integrated health care is the shared alliance between physicians and hospital services.

METHODS

The study was approved under an institutional review board protocol. This observational study involved sequential implementation of a multidisciplinary team, standardized protocols, and a craniotomy care pathway using retrospective review of data.

We reviewed qualitative and quantitative results aimed to address the 5 key criteria identified in the Cochrane review for clinical pathways.[1] These criteria were 1) a multidisciplinary care team; 2) development of a pathway through use of guidelines and

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evidence-based practice; 3) a detailed, stepwise pathway covering a treatment period; 4) criteria-based steps for progression along the pathway; and 5) the aim of the intervention was to standardize care for a specific problem, procedure, or episode of care.

Data were collected from 2008 to 2017 for 3693 patients who underwent craniotomy and were hospitalized at KP Sacramento Medical Center using the top 6 diagnosis-related group (DRG) craniotomy codes ranked by admission volume in 2017 (Table 1). A data analyst (EY) used SAS software (SAS Institute Inc, Cary, NC) to read and extract inpatient craniotomy LOS data from the KP HealthConnect (Epic, Verona, WI) Hospital Regulatory table into a spreadsheet (Excel, Microsoft, Redmond, WA) using DRG coding and cross-referencing to neurosurgeons who performed this procedure during the study period. A data analyst (LP) developed and implemented programming to enable electronic capture of expanded data collection, including the searchable craniotomy-specific discharge summary template from the HealthConnect electronic medical record (EMR). These data were imported to data visualization software (Tableau, Tableau Software, Seattle, WA). Mandatory drop-down lists were designed to collect more detailed data regarding timing and indications for craniotomy, hospital-related complications, functional outcomes, discharge destinations, and avoidable delays in care (see Supplemental Material, available at: www.thepermanentejournal.org/files/2019/18-209-App.pdf). This craniotomy-specific hospital discharge data collection started in June 2016 and is ongoing (through December 2017; N = 682 craniotomy admissions). Staff in the Infection Control Division of the hospital monitored for surgical site infections (SSIs) and external ventricular drain (EVD)-related ventriculitis.

For functional outcomes, we used the Modified Rankin Scale for Neurologic Disability. In this scale, a score of 0 = no symptoms; 1 = no disability despite symptoms; 2 = slight disability but able to look after own affairs; 3 = able to walk independently but unable to manage affairs independently; 4 = unable to walk independently and unable to attend to own bodily needs unassisted; and 5 = bedbound, requiring constant nursing care. Descriptive statistical analysis was completed using Microsoft Excel (Microsoft, Seattle, WA).

Standardized Protocols List

- Craniotomy wound care
- External ventricular drain care
- Neurocritical care order set
- Neurocritical care supplementary order set
- Craniotomy pathway
- Subarachnoid hemorrhage pathway
- Cranioplasty pathway and care bundle
- Functional neurosurgery/deep brain stimulator
- Reversal of coagulopathy order set
- Subdural hematoma pathway
- Anticonvulsant guidelines
- Steroid taper guidelines
- Deep venous thrombosis prevention guidelines
- Hospital discharge summary outcome measures
- Surgical drain protocols
- Early mobilization protocols

Table 1. Example of data collection using diagnosis-related group (DRG) craniotomy codes (2017, N = 475)

DRG code	Definition	No.
23	Craniotomy with major device implant or acute complex central nervous system principal diagnosis with MCC	65
24	Craniotomy with major device implant or acute complex central nervous system principal diagnosis without MCC	36
25	Craniotomy and endovascular intracranial procedures with MCC	191
26	Craniotomy and endovascular intracranial procedures with CC	50
27	Craniotomy and endovascular intracranial procedures without CC/MCC	91
614	Adrenal and pituitary procedures with CC/MCC	42

CC = complications and comorbidities; MCC = major complications and comorbidities.

RESULTS

Inpatient Neurosurgery Service Redesign

The inpatient neurosurgery program at KP Sacramento Medical Center underwent a marked transformation between 2008 and 2017. Before implementation of an integrated inpatient neurosurgery service, the care of patients was shared between neurosurgeons for operative cases and hospitalists for nonoperative admissions such as small traumatic contusions or subdural hematomas. This model had evolved because of on-call demands on the neurosurgeons, operating room (OR) physical restraints on neurosurgeons, and a long-standing and robust hospitalist program. This shared model of care led to staff conflict because the hospitalists had variable levels of expertise and clinical confidence managing nonoperative neurosurgical admissions. The ICU used an open staffing model. Pulmonary medicine faculty comanaged neurosurgical patients receiving mechanical ventilation but signed off after successful extubations. Neurosurgeons managed their ICU patients who were not intubated, often with the assistance of hospitalists. The first neurocritical care specialist was recruited in 2007.

Summit meetings involving leadership and key stakeholders from neurosurgery, neurocritical care, and hospitalists created strong support for an integrated inpatient neurosurgery service that would include all operative and nonoperative patients directly admitted or transferred to the medical center for tertiary care neuroscience expertise. A series of loosely structured, off-site dinner meetings was held to air past complaints, to broker disputes, to mend collegial relationships, and to debate solutions.

The process built consensus for a redesign of the inpatient neurosurgery service centered around a 3-legged staffing model by neurosurgeons, neurointensivists, and "neurohospitalists." A wary subgroup of hospitalists volunteered to rotate on a weekly basis on the inpatient neurosurgery service, and we called these pioneers neurohospitalists. To provide more consistent care and to improve communication, the group agreed to use standardized order sets, discharge instructions, posthospital discharge follow-up, and treatment-specific protocols. A closed neurocritical care unit was created, and all patients requiring ICU-level care were also seen daily and comanaged by neurointensivists. Protocols and care pathways were created using neurosurgery department subcommittees. Draft protocols and pathways were presented and critiqued during off-hours journal club dinner meetings and circulated via an intradepartmental email for comments. The finalized protocols and pathways were reviewed and adopted at departmental meetings (see Sidebar: Standardized Protocols List).

In January 2008, the inpatient neurosurgery service was implemented. All patients on the service were reviewed at daily interdisciplinary morning rounds (as described in the next section). Within months, we observed fewer conflicts between neurosurgeons and hospitalists. The new model also improved collegial relationships with physicians at outlying medical centers who requested urgent referrals and patient transfers. The neurocritical care unit worked with referring practitioners to coordinate the transfer and to address care needs before transfer, such as blood pressure management, airway protection, anticonvulsants, corticosteroids, and reversal of coagulopathy.

Since 2010, the daily inpatient neurosurgery service census increased from an average of 15 to an average of 45. This increased service volume is reflected in the 73% rise in the number of craniotomy admissions (Figure 1). As additional staffing was needed because of growth of the inpatient service, we recruited midlevel practitioners to coordinate care for patients on the medical and surgical units and to assist with operations. This 4-legged staffing model (neurosurgeons, neurointensivists, neurohospitalists, and midlevel practitioners) was implemented in 2011 and remains a successful strategy to manage our growing case volume and case complexity.

Multidisciplinary Morning Report

A vital component of the day-to-day operation is a formal morning rounds to review all patients admitted to the inpatient neurosurgery service. The morning rounds are attended by neurosurgeons, neurointensivists, neurohospitalists, physiatrists, midlevel practitioners, and patient care coordinators. Nursing leadership from the neurocritical care unit, neurostepdown unit, and medical-surgical units also participates. Additional time is devoted to new admissions and to patients with complex care concerns or acute problems, and a treatment strategy is developed with input from the multidisciplinary team. A major advantage of morning rounds is that hospital throughput and staffing needs can be calculated up or down on the basis of anticipated daily admissions, transfers, and discharges. The rounds also provide practical educational value and promote team unity.

Neurosurgery and Neurocritical Care Protocols and Order Sets

During this transition in the inpatient neurosurgery service, HealthConnect, an Epic-based EMR, was implemented. We leveraged the EMR to standardize and improve care delivery. Protocols were created using published guidelines and group consensus (see Sidebar: Standardized Protocols List). Neurosurgery and neurocritical care order sets were developed around these protocols.

Rapid reversal of coagulopathy protocols and order sets underwent several revisions during this period using a multidisciplinary team of neurosurgeons, neurointensivists, and hematologists. The inpatient neurosurgery service stopped using fresh frozen plasma and adopted more effective agents such as recombinant factor 7 and prothrombin complex concentrates.[5] This order set underwent revision to include reversal strategies for patients receiving direct oral anticoagulants. A standardized approach was used to improve recognition and management of platelet dysfunction related to medications and trauma, particularly in unstable patients with active intracranial bleeding or requiring urgent intracranial procedures. Using platelet function assays, we observed a 38% rate (22/58 patients) of platelet dysfunction in patients with subdural hematoma, despite having adequate platelet counts.[6]

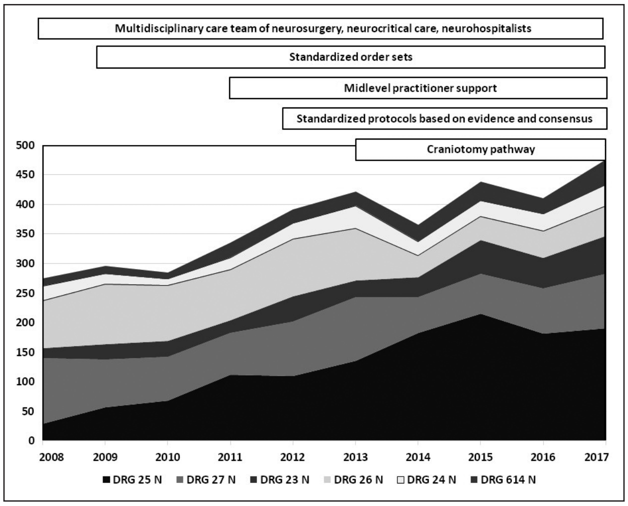

Figure 1. Craniotomy case volume by craniotomy DRG codes.[a]
[a] Time intervals for transitions in care are included. Number of cases is shown on the y-axis. DRG = diagnosis-related group.

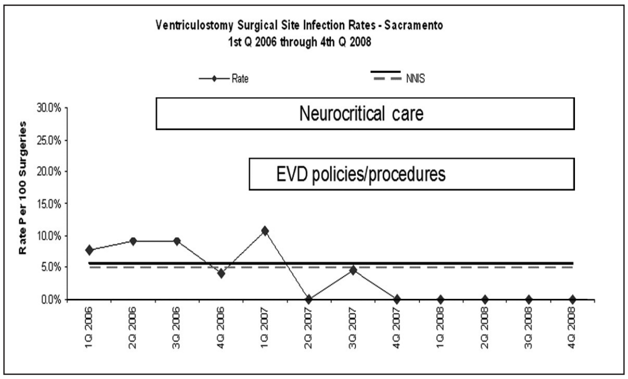

Figure 2. External ventricular drain (EVD)-related ventriculitis.
NNIS = National Nosocomial Infection Surveillance (Centers for Disease Control and Prevention); Q = quarter.

Reductions in Craniotomy, Cranioplasty, and External Ventricular Drain-Related Infections

In 2008, ventriculitis rates trended above the national average (Figure 2). The EVD insertion, wound care, cerebrospinal fluid sampling procedures, weaning protocols, and periprocedural antibiotic use were standardized, with a gratifying resolution of this problem. The craniotomy SSI rate was 2.3%, which is similar to the American College of Surgeons National Surgical Quality Improvement Program database rate of 2.04%.[7] Management

Process indicators	**Date** / **Preoperative**	**Date** / **Day of surgery**	**Date** / **POD 1**	**Date** / **POD 2**	**Date** / **POD 3**
Dx Studies	**Pre-op for Brain Mass**	___ Stat Post Op Imaging if ordered	___ Post Op MRI if ordered	___ Post Op MRI if ordered	___ Post Op MRI if ordered
Treatments Nursing Actions	___ Neurosurgery Consult ___ H&P completed ___ MRI Imaging STEALTH (Fiducials if STEALTH) ___ CBC ___ INR ___ Chem 7 ___ CT c/a/p (if requested) ___If bleeding risk, T/C 2 units PRBC ___ Steroids ___ Anticonvulsants ___ NPO ___ IVF when NPO ___ Informed consent signed/witnessed ___ Hospital staff to notify DMV if seizure activity	___ Informed consent signed/witnessed ___ AED administered ___ Neuro checks hourly ___ PACU to ICU ___ Surgical drains secured ___ SCDs ___ BP maintained in desired range ___ Hospital staff to notify DMV if seizure activity	___ Neurochecks Hourly ___ DC Art-Line ___ Surgical drains secured ___ AED prophylaxis ___ DC foley if ordered on POD 1 ___ Sodium in desired range ___ SCDs ___ Incentive Spirometer ___ Start PO after swallow evaluation ___ OOB for meals ___ Neuro exam stable or improving if not call MD ___ Absence of stridor or respiratory issues ___Hospital staff to notify DMV if seizure activity	___ DC drains if indicated ___ OOB for meals ___ Saline lock if PO> 50% ___ Surgical drains secured ___ AED prophylaxis ___ DC Foley if ordered POD 2 ___ Neuro checks Q4hrs ___ Vital signs Q4Hrs ___ Transfer to floor if neurologic exam stable and post-op imaging satisfactory ___ Laxative if no BM ___ Sodium in desired range ___ SCDs ___ Incentive Spirometer ___ Neuro exam stable or improving if not call MD ___ Absence of stridor or respiratory issues ___ Hospital staff to notify DMV if seizure activity	___ DC drains if indicated ___ OOB for meals ___Saline lock if PO> 50% ___ Dressing removed/site cleaned/ left open to air or with stocking cap ___ Surgical drains removed ___ AED prophylaxis- PO ___ DC Foley if ordered POD 3 ___ Transfer to floor if neurologic exam stable and post-op imaging satisfactory ___ Neuro checks Q8hrs ___ Vital signs Q8Hrs ___ Laxative and suppository if no BM ___ Sodium in desired range ___ Neuro exam stable or improving if not call MD ___ Absence of stridor or respiratory issues ___ SCDs-DC when walking > 150 ft ___ Incentive Spirometer ___ Hospital staff to notify DMV if seizure activity
Rehab PT/OT			___ Swallow evaluation ___ Therapy evaluations if ordered	___ Therapy evaluations if ordered	___ Therapy evaluations completed
Medications	___ Steroids ___ Anticonvulsants	___ Steroids administered ___ Antibiotics administered	___ Steroids ___ Start HeparinSC if ordered POD 1 ___ Start oral pain medications ___ IV pain medications for breakthrough pain	___ Steroids ___ Start SC Heparin if ordered POD 2 ___ Oral pain medication ___ IV pain medication for Breakthrough pain ___ Laxative if no BM	___ Steroids taper/PO ___ Start SC Heparin if ordered POD 3
Discharge Planning & Teaching	___ RN Education to Pt/Family on craniotomy OR day	___ RN Education to Pt/Family on craniotomy post op care	___ Patient care coordinator to anticipate DC needs/barriers ___ RN Education to Pt/Family on craniotomy post op care ___ Neuro-oncology follow up for primary brain tumors	___ Patient Care Coordinator to identify DC needs and relay information to ensure appropriate staffing at next level of care ___ Education to patient and family craniotomy about possible DC home date ___ Neuro-oncology follow up for primary brain tumors	___ Patient Care Coordinator to identify DC needs/barriers ___ Education to patient and family craniotomy about possible DC home date ___ Refer to SNF if home DC not possible ___ Neuro-oncology follow up for primary brain tumors

Figure 3. Example of the craniotomy pathway form implemented in 2013.

AED = antiepileptic drug; BM = bowel movement; BP = blood pressure; c/a/p = chest/abdomen/pelvis; CBC = complete blood cell count; Chem 7 = blood chemistry panel 7; CT = computed tomography; DC = discharge; DMV = Department of Motor Vehicles; DNR = do not resuscitate order; Dx = diagnostic; exam = examination findings; Foley = Foley catheter; H&P = history and physical examination; INR = international normalized ratio; IV = intravenous; IVF = intravenous fluids; MD = physician; MRI = magnetic resonance imaging; NPO = nothing by mouth; OOB = out of bed; OR = operating room; PACU to ICU = transfer from the postanesthesia care unit to the intensive care unit; pre-op = preoperative; PO = per os; POD = postoperative day; post op = postoperative; PRBC = packed red blood cells; Pt = patient; Rehab PT/OT = rehabilitation: physical therapy and/or occupational therapy; Q8hrs = every 8 hours; RN = registered nurse; SC = subcutaneous; SCD = sequential compression devices; SNF = skilled nursing facility; STEALTH = surgical navigation system (StealthStation, Medtronic); T/C = type and crossmatch.

of craniectomy now includes the recognition of a novel complication we termed external brain tamponade.[8] The role of methicillin-resistant *Staphylococcus aureus* (MRSA) colonization in SSI was investigated,[9] and we found a high correlation with postoperative neurosurgical infection rates. The MRSA-specific perioperative care bundles were developed for MRSA-colonized patients, and SSI rates fell from 32.1% to 7.4% in this high-risk population. Elevated rates of postoperative complications after cranioplasty were also recognized at our center and other neurosurgical centers.[10] We developed a perioperative cranioplasty bundle and published the results of our improved outcomes.[10] We observed the following complication rates without (n = 21) and with (n = 36) the bundle: SSI (n = 5, 23.8% vs n = 1, 2.8%) and repeated cranioplasty (n = 4, 19% vs n = 0, 0%). Because both craniectomy and cranioplasty procedures have substantial complication rates, we established and published a protocol that lowers craniectomy rates for patients with hemispheric stroke by 60% without any adverse effects on either mortality rates or survival with severe disabilities.[11] Under this protocol, we managed 30 patients with hemispheric stroke aged 18 to 60 years, and 12 patients (40%) required decompressive hemicraniectomy. All 30 patients would have undergone decompressive hemicraniectomy under the inclusion criteria for the DECIMAL, DESTINY, and HAMLET European randomized controlled trials.[11]

Table 2. Craniotomy indication data collected using standardized craniotomy discharge summaries (N = 596)

Craniotomy indication	Percentage[a]
Primary brain tumor, intraaxial	22
Primary brain tumor, extraaxial	14
Endonasal approach for mass	14
Subdural hematoma, subacute or chronic	11
Deep brain stimulator	10
Neurovascular disease (aneurysm, vascular malformation)	8
Acute subdural hematoma	5
Ventricular shunt	5
Metastatic brain tumor	4
Postoperative craniotomy infection	2
Primary intracerebral hemorrhage	2
Combined HNS/NS tumor resection	1
Other	1

[a] Sum of complications is less than 100% because of rounding.
HNS = head and neck surgeon; NS = neurosurgeon.

Table 3. Postoperative complications during hospital stay for consecutive craniotomy discharge summaries (N = 649)

Postoperative complication	Percentage[a]
None	92
New cranial nerve deficit	2.5
Seizure	1.5
Diabetes insipidus	1.5
Encephalopathy prolonging stay	1.4
New motor deficit	1.2
Unplanned return to OR	1.2
New neurocognitive deficit	0.8
CSF leak	0.8
Lower extremity DVT	0.6
Symptomatic postoperative hematoma	0.3
Pulmonary embolus	0.3
CAUTI	0.3
Ventilator-associated pneumonia	0.2

[a] Sum of complications is above 100% because patients may have had more than 1 complication.
CAUTI = catheter-acquired urinary tract infection; CSF = cerebrospinal fluid; DVT = deep venous thrombosis; OR = operating room.

Craniotomy Pathway Development and Implementation

In May 2013, the craniotomy pathway was implemented (Figure 3). The development and implementation was coordinated with nursing leadership in the neurocritical care unit, neurostep-down unit, and the medical-surgical nursing units. Further reductions in hospital LOS were observed after the implementation of the pathway, and these reductions have been sustained over 4 years (Figure 4). Unplanned 30-day hospital readmission rates in 2017 were 8.2% (39/475) due to SSI (1.7%), nonsurgical infections (1.7%), delayed intracranial bleeding largely due to recurrent subdural hematomas (1.5%), thromboembolic events (1%), seizures (0.6%), and other causes (1.7%).

Data Collection Using Craniotomy Discharge Summary Template

Using DRG-based data collection, we were confident that hospital LOS for patients who underwent craniotomy was improving (Figure 4). The searchable data elements in the EMR did not capture detailed information about hospital complications, outcomes, and reasons for delays in hospital discharge. A manual review of craniotomy electronic charts is time-consuming and not a sustainable solution.

In June 2016, the department developed and implemented an EMR-based, searchable standardized craniotomy discharge summary (see Supplemental Material, available at: www.thepermanentejournal.org/files/2019/18-209-App.pdf). This template captures important details about craniotomy indications (Table 2), timing of craniotomy (20% emergent, 18.6% urgent, 61.4% elective, n = 681), complications (Table 3), functional outcomes (Figure 5), causes for delayed hospital discharges (Table 4), and postdischarge destinations (Table 5). Current use of the craniotomy discharge summary template over the last 6 months of 2017 averaged 84%. There is ongoing work using related EMR templates to capture important clinical information during preoperative craniotomy planning and outpatient postoperative care. We are currently reviewing information regarding delays in hospital discharge to identify opportunities to further improve care.

Cost-Savings Analysis

Using 2017 craniotomy volume data (Table 1), we calculated a reduction of 4390 hospital days compared with 2008 LOS data. In 2017, the 475 patients who underwent craniotomy required 2599 hospital days, but they would have required 6989 hospital days using 2008 LOS data. On the basis of an average hospital-adjusted

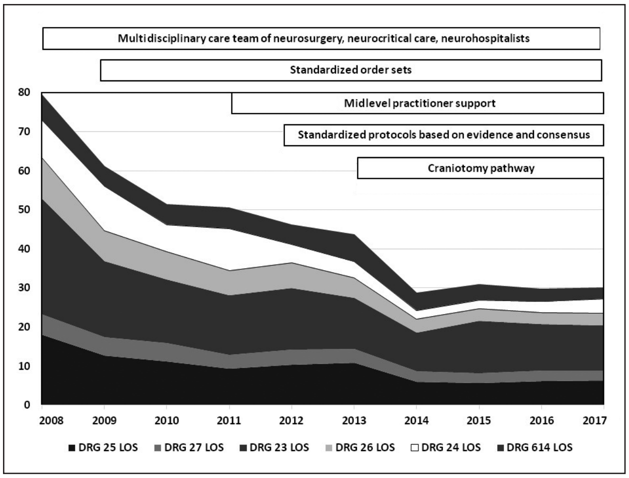

Figure 4. Length of stay by craniotomy DRG.[a]
[a] Number of days in the hospital is shown on the y-axis.
DRG = diagnosis-related group; LOS = length of stay.

expenses per inpatient day rate of $3341, the reduction in hospital days indicates a decrease in hospital expenses of $14,666,990/y.[12]

The improvements related to EVD-related ventriculitis, MRSA-related craniotomy SSIs, cranioplasty-related SSI, and reductions in hemicraniectomy after hemispheric stroke all led to a reduction in hospital costs. For example, treatment of deep SSIs after craniotomy usually requires repeated hospitalization, return to the OR for wound washout and removal of bone flap and hardware, and typically 6 weeks of extended intravenous antibiotics. Additional costs arise from an additional surgical procedure (cranioplasty) to manufacture and replace the explanted bone flap (cranioplasty) with a custom prosthesis.

DISCUSSION

We observed major improvements in quality and care efficiency during a stepwise transition of craniotomy care to multidisciplinary teams, protocols, and care pathways. To our knowledge, this is the first published report regarding the effect of this treatment model on craniotomy hospital care. During this period, the inpatient neurosurgery service at KP Sacramento Medical Center experienced substantial growth in case volume and complexity for patients who underwent craniotomy. The improved care quality and efficiency are key reasons the medical center was able to accommodate the increased craniotomy volume without expanding ICU or medical-surgical unit beds or creating a craniotomy case backlog. For example, 275 patients who underwent craniotomy required 2768 hospital days in 2008, compared with 475 patients who underwent craniotomy requiring 2599 hospital days in 2017. Once hospital bed capacity is outstripped, costs further escalate related to hospital construction costs or outsourcing of patient care.

The 4-legged staffing model recognizes and leverages the different skill sets that each clinician brings to the inpatient service. Previously, the on-call neurosurgeon was juggling patient referrals, OR, rounding, and discharging. The current practice model delegates many aspects of this care to the neurointensivists, neurohospitalists, and midlevel practitioners under structured protocols. Because of the craniotomy pathway and morning rounds, patient transfers and discharges are anticipated early in the workday. The neurosurgeon is off-loaded from this work and experiences fewer delays and interruptions while prioritizing on-call duties, new patient consultations, preoperative planning, OR duties, and availability for postoperative complications.

An important advantage of the craniotomy care pathway is the transparency of the care process throughout the inpatient stay. Patients and families experience greater staff cohesion regarding postcraniotomy care, including the hospital discharge process and outpatient postoperative care. The protocols and pathways have improved care consistency regarding postdischarge medications, instructions, wound care, activity level, and appointments. The recent work using the craniotomy discharge summary template has provided more accurate answers to questions by patients and families about postcraniotomy care, complications, and outcomes. For urgent and elective craniotomies, much of this information can be introduced to patients and families during the preoperative stage.

During the transition period from 2008 to 2017, the neurosurgery program expanded to include 2 additional hospitals providing Level II trauma and also elective neurosurgery procedures. The investment to develop the protocols and pathways at our center paid off tremendously when bringing these additional programs on board. These protocols and order sets were implemented with minimal changes at the new neurosurgery sites. To staff these additional centers, neurosurgeons were recruited and the group grew from 5 to 15. The new faculty were quite accepting of these protocols and order sets, because they had been developed and vetted by more senior neurosurgeons. Also, the nursing and pharmacy staff were quite familiar with them.

We are currently using the expanded data elements collected from the searchable craniotomy discharge summary template

Table 4. Problems contributing to discharge delays after craniotomy (N = 640).

Craniotomy pathway	Percentage
Expected LOS	92
Medical delay	3.4
Surgical delay	2
SNF bed availability	0.8
Acute rehabilitation bed availability	0.6
Pain control	0.5
Home discharge delay	0.3

LOS = length of stay; SNF = skilled nursing facility.

Table 5. Hospital discharge location for consecutive craniotomy discharge summaries (N = 682)

Hospital discharge location	Percentage
Private residence	89.8
Skilled nursing facility	6.5
Died	2.4
Acute rehabilitation	1
Transfer to another acute care facility	0.3

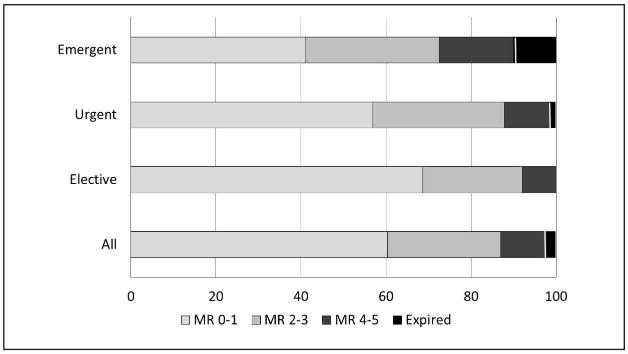

Figure 5. Functional outcomes at time of hospital discharge (N = 649).[a]

[a] Timing for craniotomy was emergent if completed in 24 hours or less, urgent if completed in 7 days or less, and elective if completed in more than 7 days. Modified Rankin (MR) score of 0 = no symptoms; 1 = no disability despite symptoms; 2 = slight disability but able look after own affairs; 3 = able to walk independently but unable to manage affairs independently; 4 = unable to walk independently and unable to attend to own bodily needs unassisted; 5 = bedbound, requiring constant nursing care. Percentage of patients is shown on the x-axis.

to continuously monitor quality and efficiency of care. We have also found it useful during conversations with patients and families. For example, we can discuss hospital outcomes related to the indications and the timing of craniotomy (Figure 5). For example, rates of death or serious disability (modified Rankin scores deceased to 4 and 5, respectively) at hospital discharge vary from 27% for emergent craniotomies, 12% for urgent craniotomies, and 8% for elective craniotomies. When patients deviate from the expected craniotomy pathway, the staff understand the importance of looking for causes and remedies, particularly medical and surgical complications (Tables 3 and 4). The improved granularity of data collection at hospital discharge has been helpful to measure the success of inpatient care and to focus on opportunities to improve care (Tables 3 and 4).

The level of evidence of this study is Level II-3, which is "evidence obtained from multiple time series designs with or without the intervention" based on definitions from the US Preventive Services Task Force.[13] Because of the multitude of changes that occurred during this transition period, we are unable to measure the impact of individual interventions. A strength of the study is its fulfillment of Cochrane review standards. The KP model of care closely integrates and aligns physicians and hospital-based care. Although there are always internal conflicts between specialists and hospital-based service lines, the KP group practice model and compensation strategies reduce conflicts over traditional turf wars for patient referrals and procedural volume. Because this is a single-center study, future studies are needed to determine whether these findings can be reproduced in other care settings. The long-term utility of the craniotomy discharge summary template will require further study. The hospital-based focus of this study does not include posthospital discharge data regarding functional outcomes data and posthospital discharge-related complications. Formal measures of patient and physician satisfaction and quality of life indexes were not included in this report.

CONCLUSION

Our observational study suggests that the transition of craniotomy care from the traditional model to a model incorporating multidisciplinary teams, protocols, and pathways has reduced complication rates, improved hospital LOS, and increased professional collegiality and satisfaction. ❖

Disclosure Statement

The author(s) have no conflicts of interest to disclose.

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References

1. Rotter T, Kinsman L, James EL, et al. Clinical pathways: Effects on professional practice, patient outcomes, length of stay and hospital costs. Cochrane Database Syst Rev 2010 Mar 17;3:CD006632. DOI: https://doi.org/10.1002/14651858.CD006632.pub2.
2. Florman JE, Cushing D, Keller LA, Rughani AI. A protocol for postoperative admission of elective craniotomy patients to a non-ICU or step-down setting. J Neurosurg 2017 Dec;127(6):1392-7. DOI: https://doi.org/10.3171/2016.10.JNS16954.
3. Osorio JA, Safaee MM, Viner J, et al. Cost-effectiveness development for the postoperative care of craniotomy patients: A safe transitions pathway in neurological surgery. Neurosurg Focus 2018 May;44(5):E19. DOI: https://doi.org/10.3171/2018.2.FOCUS1812.
4. Venkatraghavan L, Bharadwaj S, Au K, Bernstein M, Manninen P. Same-day discharge after craniotomy for supratentorial tumour surgery: A retrospective observational single-centre study. Can J Anaesth 2016 Nov;63(11):1245-57. DOI: https://doi.org/10.1007/s12630-016-0717-8.
5. Woo CH, Patel N, Conell C, et al. Rapid warfarin reversal in the setting of intracranial hemorrhage: A comparison of plasma, recombinant activated factor VII, and prothrombin complex concentrate. World Neurosurg 2014 Jan;81(1):110-5. DOI: https://doi.org/10.1016/j.wneu.2012.12.002.
6. Akins PT, Guppy KH, Sahrakar K, Hawk MW. Slippery platelet syndrome in subdural hematoma. Neurocrit Care 2010 Jun;12(3):375-80. DOI: https://doi.org/10.1007/s12028-010-9336-3.
7. McCutcheon BA, Ubl DS, Babu M, et al. Predictors of surgical site infection following craniotomy for intracranial neoplasms: An analysis of prospectively collected data in the American College of Surgeons National Surgical Quality Improvement Program database. World Neurosurg 2016 Apr;88:350-8. DOI: https://doi.org/10.1016/j.wneu.2015.12.068.
8. Akins PT, Guppy KH. Sinking skin flaps, paradoxical herniation, and external brain tamponade: A review of decompressive craniectomy management. Neurocrit Care 2008;9(2):269-76. DOI: https://doi.org/10.1007/s12028-007-9033-z.
9. Akins PT, Belko J, Banerjee A, et al. Perioperative management of neurosurgical patients with methicillin-resistant Staphylococcus aureus. J Neurosurg 2010 Feb;112(2):354-61. DOI: https://doi.org/10.3171/2009.5.JNS081589.
10. Le C, Guppy KH, Axelrod Y, et al. Lower complication rates for cranioplasty with peri-operative bundle. Clin Neurol Neurosurg 2014 May;120:41-4. DOI: https://doi.org/10.1016/j.clineuro.2014.02.009.
11. Akins PT, Axelrod YV, Arshad ST, Guppy KH. Initial conservative management of severe hemispheric stroke reduces decompressive craniectomy rates. Neurocrit Care 2016 Aug;25(1):3-9. DOI: https://doi.org/10.1007/s12028-016-0270-x.
12. Hospital adjusted expenses per inpatient day [Internet]. San Francisco, CA: Henry J Kaiser Family Foundation; 2016 [cited 2018 Jul 3]. Available from: www.kff.org/health-costs/state-indicator/expenses-per-inpatient-day/?currentTimeframe=0&sortModel=%7B%22colId%22:%22Location%22,%22sort%22:%22asc%22%7D.
13. US Preventive Services Task Force. Guide to clinical preventive services: Report of the US Preventive Services Task Force. DIANE Publishing; 1989: Appendix A.