Economic & Quality Benefits of Minimally Invasive Parafascicular Surgery (MIPS)

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SUMMARY STATEMENTS

- Neurosurgery represents one of the costliest areas within the American healthcare system. Craniotomies for brain tumor removal and intracerebral hemorrhage evacuation account for a substantial portion of these expenditures.
- Several economic initiatives aimed at managing healthcare costs while improving quality of care are beginning to be applied in neurosurgical units. These initiatives include the Triple Aim of Healthcare, Enhanced Recovery After Surgery (ERAS) and "safe transitions" protocols.
- Minimally invasive parafascicular surgery (MIPS) has been shown to reduce healthcare costs in a number of ways including reduced length of stay, risk of morbidity/mortality and improving quality of life.
- Institutional realization of the economic benefits of MIPS can be initiated through training staff on a four-tier process.

ABSTRACT

Neurosurgery represents one of the costliest areas within the American Healthcare System. The national bill for treatment of brain tumors is over $27 billion dollars while treatment of intracerebral hemorrhage (ICH) is over $35 billion. Craniotomies for brain tumor removal and ICH evacuation account for a substantial portion of these expenditures. Efforts to reduce costs while improving patient outcomes and quality of life are tenets of initiatives such as Triple Aim supported by Enhanced Recovery After Surgery (ERAS) and "safe transitions" protocols. These initiatives are gaining widespread support throughout hospital systems, including neurosurgical units, and focus on minimally invasive surgeries to improve patient outcomes and control expenses. **M**inimally **I**nvasive **P**arafascicular **S**urgery (MIPS) is a deficit sparing alternative neurosurgical approach to conventional treatments for brain tumors and ICH. MIPS incorporates key technologies and fits into cost saving economic models such as Triple Aim. MIPS is less invasive than traditional craniotomies, often allowing for awake anesthesia and preservation of eloquent brain tissue by parting brain tissue along a parafascicular route. Less invasive surgeries are associated with lower morbidity/mortality, and a reduction in

post-operative complications. Thus, MIPS can facilitate cost savings through multiple avenues including reduced length of hospital and ICU stay and mortality, while improving post-surgical quality of life and patient functional status. Finally, MIPS is a desirable alternative for patient-consumers seeking less invasive options for their treatment. In summary, compared with a traditional craniotomy, MIPS requires less invasive access resulting in improved cosmetic satisfaction, reduction in LOS and complication rates and greater likelihood of using awake anesthesia, factors that collectively lead to lower expenditures and improved patient outcomes. Neurosurgeons can receive MIPS training through participation in a hands-on experiential course lead by neurosurgeon peers.

THIS PAPER WILL DESCRIBE

- The current financial burden from brain tumors and ICH treatment on patients and the healthcare system
- Economic initiatives that strive to control healthcare costs while maintaining quality
- How MIPS accomplishes these key economic initiatives while addressing patients' needs
- A pathway to include MIPS as part of an organization's care protocol

NEUROSURGERY PRESENTS A COST CHALLENGE TO AMERICAN HEALTHCARE

Neurosurgery represents one of the costliest areas within the American Healthcare System. The National bill for treatment of brain tumors is over $27 billion dollars while treatment of intracerebral hemorrhage (ICH) is over $35 billion.[1] Brain tumors and ICH affect a substantial portion of Americans and have a profound effect on quality of life and healthcare expenditures. (Tables 1 A-E, Figure 1)

Patients who undergo complex traditional craniotomy or ICH evacuation procedures within or near eloquent sensory/motor areas or within deep brain have complication rates which can approach upwards of 15%[2-4] and require the need for post-discharge aftercare in skilled nursing or rehabilitation facilities. Older adults are at particular risk for post-operative brain surgery complications, yet may benefit from surgery.[5]

Throughout the healthcare landscape, there are numerous examples of organizations, physicians and patients looking toward new technology to improve care and outcomes while managing skyrocketing costs. Neurosurgery is no exception.

Within the neurosurgery field, a major component of the overall economic burden is initial hospitalization and length of stay (LOS).[6] Craniotomy and ICH surgery are particularly high-risk procedures. Healthcare organizations frequently cite LOS as a primary target for cost containment. However, LOS in craniotomy patients is largely driven by pre-existing co-morbidities and surgical complications.[6,7] With this in mind, one area of cost containment should be mitigation of surgical complications through use of less invasive surgical access methods. (Figure 2)

Spontaneous intracerebral hemorrhage (ICH) is a devastating and costly event associated with high mortality and morbidity. Previous studies sought to identify patient or treatment characteristics associated with higher hospital costs;[8-20] patient comorbidity is an important cost-driving factor. Specogna et al.[11] reported in 2017 the mean cost of hospital treatment during the first year after ICH was $20,165 per patient. The lifetime cost per ICH is estimated to be $6 Billion.[12]

For tumor resection, the estimated financial burden is less clear due to the heterogeneous nature of tumors, however, a typical craniotomy costs about $50,000 and costs to treat a malignant brain tumor can exceed $700,000 if using a combination of surgery, radiation and chemotherapy.[12] According to the Brain Tumor Foundation, the burden of treating a glioblastoma is about $450,000.[13] Major complications can add, at a minimum an additional $50,000.[14]

The more invasive the surgery, the higher probability of infection and post-operative complications.

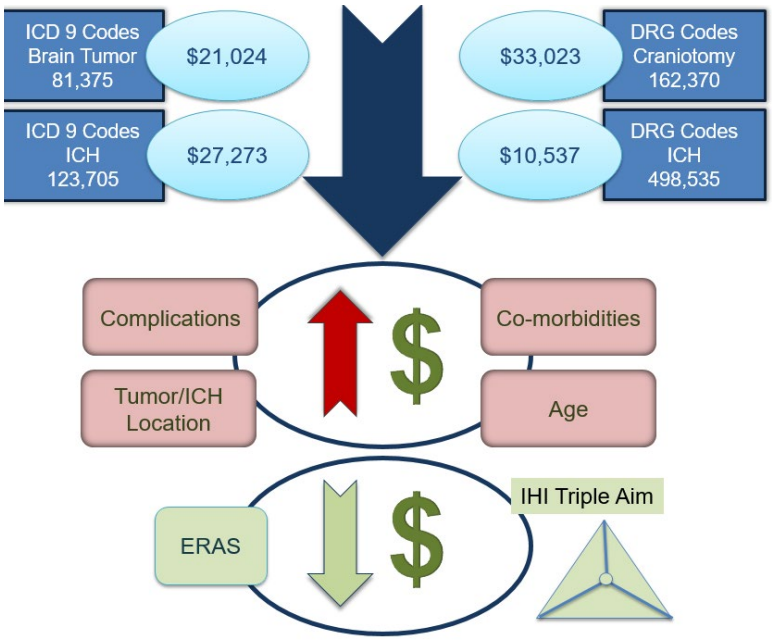

Figure 1: Economics of brain tumors and ICH[1]

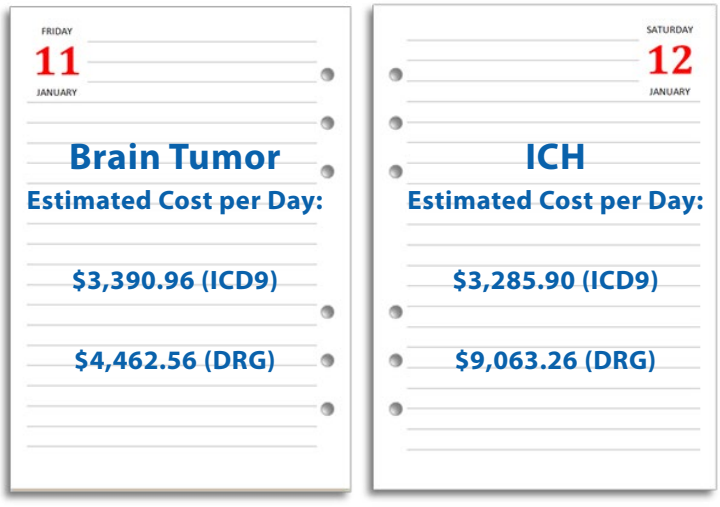

Figure 2:
Estimate Daily Costs of Brain Tumor and ICH.
Based on 2014 HCUP ICD-9 and DRG codes for brain tumor (191.0-191.9, 198.3, 198,4 and 23-27) ICH (430, 431, 432.9, 432,432.1 and 64,65,66). Numbers reflect mean average cost divided by LOS[1]

ECONOMIC & QUALITY BENEFITS OF MINIMALLY INVASIVE PARAFASCICULAR SURGERY (MIPS)

Several studies associate craniotomy complications with increased costs and LOS in tumor patients[6] and in ICH patients.[11]

SUMMARY

- Neurosurgical costs related to ICH or craniotomy for tumor resection can be summarized by the 3 C's:
  - » Complexity
  - » Complications
  - » Co-morbidities
- Economic and treatment strategies that mitigate the 3 C's can be implemented

TRIPLE AIM SUPPORTED BY ERAS & "SAFE TRANSITIONS" INITIATIVES THAT CURB INSTITUTIONAL COST & ENHANCE QUALITY

The Institute of Healthcare Improvement's (IHI) Triple Aim[15] is designed to help health care organizations improve the patient's experience of care, improve the health of populations, and reduce per capita costs of health care with quality defined from the perspective of the patient. Delivering quality of care while achieving good patient outcomes and mitigating spending is a paragon of any healthcare service. Institution and healthcare cost savings focus on three key areas: Limiting post-operative complications with peri-, and intra-operative strategies through Enhanced Recovery After Surgery (ERAS) protocols,[16] and advancing the use of procedures, techniques and protocols that identify patients who do not need post-surgical ICU care and are instead transferred to the floor.[17,18] Central to all of these initiatives is the use of minimally invasive surgery.

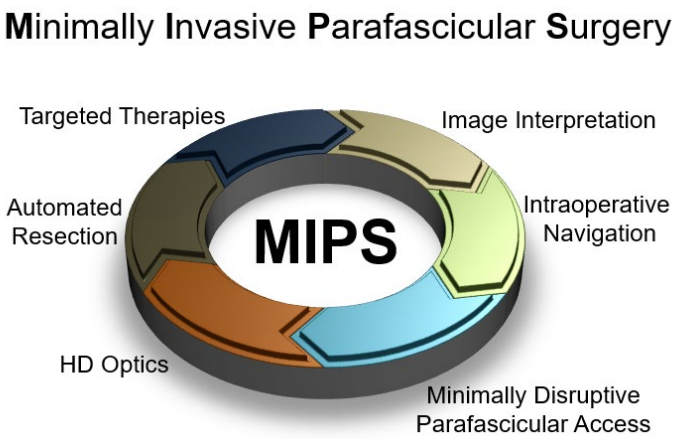

Figure 3: The six components of MIPS[19]

DELIVERING ON THE TRIPLE AIM: MIPS SUPPORTED BY THE BRAINPATH® APPROACH

MIPS incorporates six key components that work in concert as a deficit sparing parafascicular minimally invasive approach to brain surgery.[19] (Figure 3) These interdependent technologies harness the latest science, allowing the neurosurgeon to strategically approach each brain tumor or ICH in a tailored manner.

MIPS SUPPORTED BY THE BRAINPATH APPROACH COMPARES FAVORABLY AGAINST CONVENTIONAL TREATMENTS

The BrainPath Approach is the world's first and only navigable parafascicular approach using transulcal access, (BrainPath®) automated removal (Myriad™), and biological preservation of resected tissue (Tissue Preservation System). To date, it has been used in over 9,000 procedures worldwide.[20] The BrainPath Approach is characterized by a robust peer reviewed publication portfolio of over 70 abstracts, posters and journal articles that support its use as part of MIPS.[21-82]

The BrainPath Approach as a part of MIPS, has demonstrated the following benefits in support of the key tenets of the Triple Aim: improve health of populations, patient experience of care and reduce per capita cost of healthcare.

- Reduced LOS [24,29,42,44,45,50,53,62,66,67,73]
- Reduced complications[24,29,33,38,39,42,44,45,50,53,54,57,61,67,72,74]
- No reports of surgery-related infection[29,45,72,67]
- No reports of device related in hospital mortality[24,29,33,39,42,44,45,50,54,57,61,72,73,74] even in higher risk >65 year age group[29]
- Reduced operative times[61,67]
- Foster strategies conducive to post anesthesia recovery transfer to floor vs. ICU[29,33,42,44,54,61,67,72]
- Support multiple reimbursement paradigms within a clinician-driven treatment plan that includes surgery and adjuvant therapies[16,32,66,79]

There are several areas in the patient's neurosurgical care journey where MIPS can intervene in an effort to control costs. For example, McLaughlin[83] points to intraoperative strategies that can reduce the duration of OR time and postoperative strategies that can reduce ICU LOS for some patients. (Figure 4)

Other studies have analyzed the cost-effectiveness of different treatment modalities for brain tumors[84-91] and cost or charges of the hospitalization after craniotomy for tumor resection.[6] Similar studies exist for ICH.[8-11]

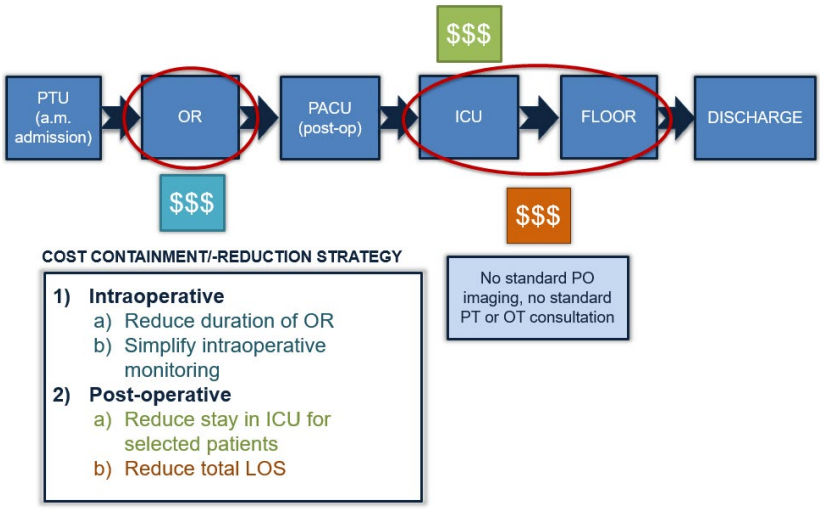

Figure 4: Component of ERAS in Neurosurgery

MIPS supported by the BrainPath Approach (MIPS-BP) was investigated as part of the Triple Aim at a single center where traditional ICH or brain tumor surgery was compared with MIPS-BP.[66] **Table 2** shows significant estimated cost savings with MIPS-BP for ICH and meaningful cost savings with brain tumor.[66]

Table 2A, B: Indiana University showed cost savings using BrainPath® in both ICH and brain tumor

A: ICH

	Traditional	BrainPath®
Number of patients	41	14
Mean ICU days	11.9	4.4
Estimated cost savings		$324,208
Readmissions at 30 days	3/41	0/8
No readmissions	38/41	8/8
Mortality	12/41	1/8

B: Brain tumor

	Traditional	BrainPath®
Number of patients	167	14
Mean ICU days	1.8	1.0
Estimated cost savings		$22,478
Readmissions at 30 days	15/167	2/10
No readmissions	152/167	8/10
Mortality	18/167	3/10

MIPS SUPPORTED BY THE BRAINPATH APPROACH:

Advances ERAS Objectives

The BrainPath Approach as part of MIPS supports the key tenants of an ERAS protocol[79] because it promotes several key elements.[16] (Figure 5)

- Minimally invasive[16,79]
- Less post-operative pain[16]
- Awake anesthesia which can contribute to less post-operative nausea and vomiting[16,32]
- Faster recovery[4,29,42,44,45,50,53,62,66,67,73]
- Greater cosmetic satisfaction[92]
- Higher patient satisfaction[16]

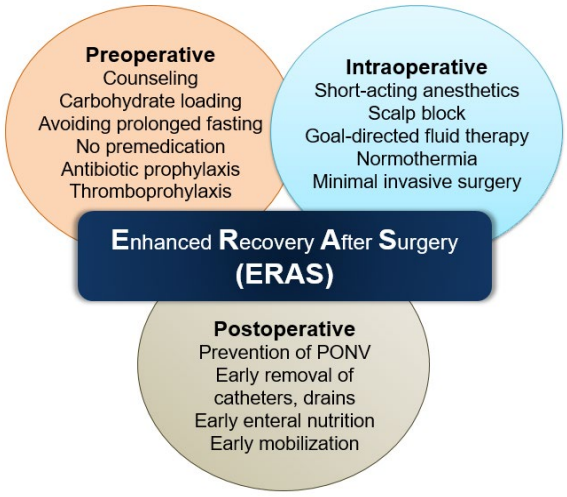

Figure 5: Characteristics of Enhanced Recovery After Surgery (ERAS) protocols

Can Facilitate "Safe Transitions" Protocols

Some craniotomy patients can be safely managed outside the ICU in the post-operative period.[17,18] These patients tend to be younger without co-morbidities, who have awake surgery and experience less blood loss and reduced operative times. Indeed, MIPS supported by the BrainPath Approach may make transfer from post-anesthesia to the floor instead of the ICU more likely since the premise of the surgery is being less invasive, controlling blood loss, minimizing operative times and fostering surgery under awake conditions.[29,33,42,44,54,61,67,72] This can result in cost savings.[66] Osorio et al.[18] utilized a "safe transitions" pathway for ten low-risk brain tumor patients undergoing craniotomy, reporting savings of $22,560 per patient; these results are similar to those reported by Norton et al.[66] (Table 2B) Therefore, it can be surmised including MIPS supported by the BrainPath Approach into a safe transitions protocol may foster post-surgical transfer to a stepdown unit versus the neurosurgical ICU.

Meets The Needs Of Patients

When it comes to "quality," in the brain tumor patient population, the National Brain Tumor Society[93] NBTS survey of 1851 patients and caregivers reports three priorities for future brain tumor treatments (Figure 6).

Other studies have confirmed the merits of less invasive brain surgeries in reducing post-operative pain and improving patient satisfaction with cosmetic outcomes.[92]

Meeting patient's needs with MIPS-BP, could make a hospital more competitive. Today's economically savvy patients research surgical services before selecting a facility, seeking the hospital most likely to provide cost-effective procedures that produce the best outcomes.[94]

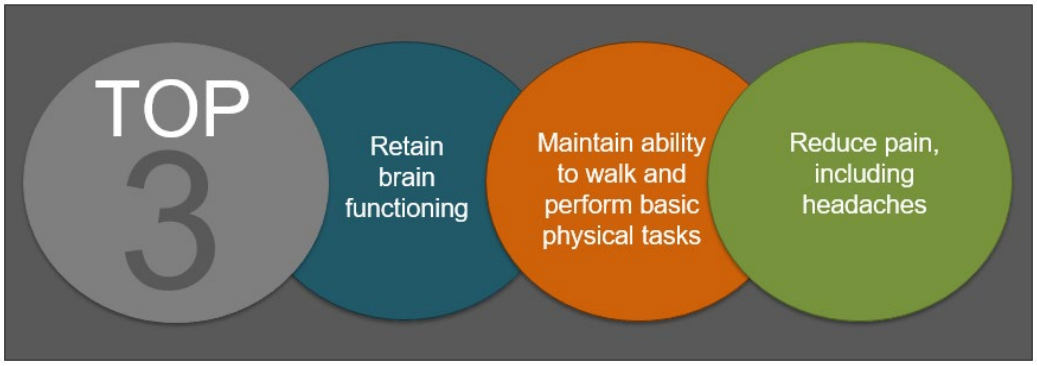

Figure 6: Results from the National Brain Tumor Society's 2014 Clinical Trial Endpoints Survey[93]

TAKE ACTION TO REALIZE ECONOMIC BENEFITS OF MIPS-BP

BrainPath's demonstrated scientific evidence and economic benefit pedigree is well-cited. Institutional change requires a champion who initiates through scientific evidence and involves a four-tier process.[79]

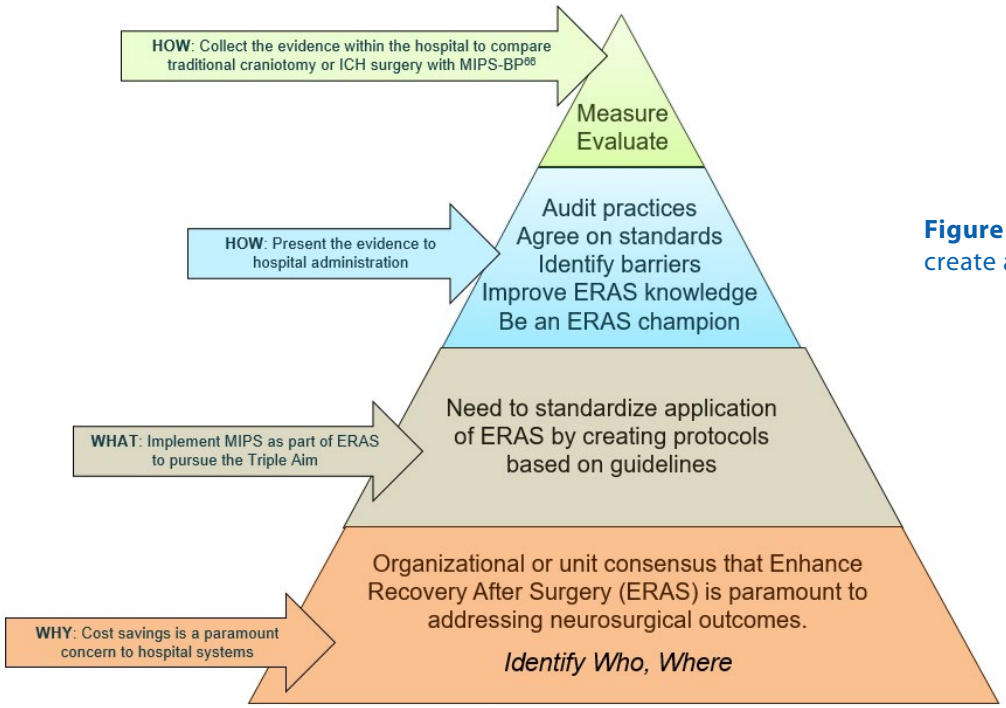

Figure 7: Four Tier Process to create an ERAS protocol[79]

Implementation of MIPS requires an organizational champion that shares the merits of MIPS with administration and colleagues. Neurosurgeons can become MIPS champions by participating in a hands-on MIPS training course taught by neurosurgeon peers.

SUMMARY

Neurosurgery is a highly complex discipline involving treatment of life changing and financially stressful health events like brain tumors and ICH. Costs are associated with the three C's: Complexity, Complications and Co-morbidities. MIPS mitigates surgical complexity and complications by providing less invasive access. Further patients with co-morbidities may benefit from MIPS as it fosters awake anesthesia and less recovery time. The overall concept of MIPS is synergistic with key tenets of multiple cost saving initiatives like ERAS, Triple Aim and "safe transitions" protocols. Neurosurgeons interested in MIPS training can participate in didactic and hands-on courses offered at various times throughout the year in the United States. To learn more about the MIPS approach and associated research and patient cases, visit the Subcortical Surgery Group website at www.subcorticalsurgery.com

Table 1A, Brain Tumor (All Codes, Includes Biopsy 191.0-191.9, 198.3, 198.4, 225.0, 225.2)

	2014	2015
Total number of discharges:	100,430	n/a*
Mean average cost:	$22,155	$23,084
National bill:	$8,503,596,384	n/a
Average LOS:	6.1 days	6.2 days
In hospital mortality:	3.39%	3.44%
Routine discharge:	51.0%	50.16%
Another short term hospital:	3.8%	2.87%
Another institution (nursing home, rehab):	24.28%	24.55%
Home health care:	17.87%	18.51%
Medicare:	41.18%	42.14%
Medicaid:	13.13%	12.67%
Private insurance:	39.32%	39.19%
Uninsured:	3.16%	2.90%

*Data are limited due to ICD 9 to 10 transition

Table 1B, Brain Tumor (All Codes, Excludes Biopsy 191.0-191.9, 198.3, 198.4)

	2014	2015
Total number of discharges:	81,375	n/a*
Mean average cost:	$21,024	$21,826
National bill:	$6,499,920,671	n/a
Average LOS:	6.2 days	6.4 days
In hospital mortality:	4.0%	4.08%
Routine discharge:	48.22%	47.28%
Another short term hospital:	3.26%	2.99%
Another institution (nursing home, rehab):	24.53%	25.17%
Home health care:	19.48%	19.97%
Medicare:	41.87%	42.53%
Medicaid:	13.55%	12.91%
Private insurance:	38.32%	38.48%
Uninsured:	2.99%	2.91%

*Data are limited due to ICD 9 to 10 transition

Table 1C, Craniotomy MS-DRG: 23-27 (Excludes Biopsy)

	2014	2015
Total number of discharges:	162,370	n/a*
Mean charges:	$128,640	n/a*
Mean average cost:	$33,023	$34,012
National bill:	$20,865,511,875	n/a
Average LOS:	7.4 days	7.3 days
In hospital mortality:	6.63%	6.45%
Routine discharge:	55.36%	54.75%
Another short term hospital:	1.69%	2.02%
Another institution (nursing home, rehab):	26.43%	28.91%
Home health care:	9.68%	9.89%
Medicare:	37.81%	38.82%
Medicaid:	14.86%	15.03%
Private insurance:	39.63%	38.71%
Uninsured:	3.83%	3.76%

Table 1D, ICH: ICD 9 Codes (430, 431, 432.9, 432, 432.1)

	2014	2015
Total number of discharges:	123,705	n/a*
Mean charges:	$112,771	n/a*
Mean average cost:	$27,273	$28,071
National bill:	$13,900,854,195	n/a
Average LOS:	8.3 days	8.4days
In hospital mortality:	20.35%	19.82%
Routine discharge:	26.09%	26.23%
Another short term hospital:	4.22%	3.98%
Another institution (nursing home, rehab):	39.88%	40.42%
Home health care:	8.75%	8.90%
Medicare:	56.51%	56.41%
Medicaid:	11.65%	11.70%
Private insurance:	23.40%	23.77%
Uninsured:	5.62%	5.36%

Table 1E, ICH: MS-DRG: 64, 65, 66

	2014	2015
Total number of discharges:	498,535	n/a*
Mean charges:	$41,691	n/a*
Mean average cost:	$10,537	$10,839
National bill:	$20,795,991,333	n/a
Average LOS:	4.6 days	4.6days
In hospital mortality:	7.12%	6.89%
Routine discharge:	34.45%	34.62%
Another short term hospital:	3.09%	2.96%
Another institution (nursing home, rehab):	41.54%	41.34%
Home health care:	12.82%	13.19%
Medicare:	65.34%	65.01%
Medicaid:	8.76%	9.10%
Private insurance:	18.82%	19.14%
Uninsured:	4.79%	4.40%

Source: HCUPnet, Healthcare Cost and Utilization Project. Agency for Healthcare Research and Quality, Rockville, MD. https://hcupnet.ahrq.gov/. For more information about HCUP data see http://www.hcup-us.ahrq.gov/1

In 2014, an estimated 100,430 patients were treated for brain tumors (benign and malignant) [ICD-9-CM 191.0-191.9; 198.3,198.4, 225.0, 225.2]. The reported mean hospital cost was $22,155, the aggregate charges or National Bill was

$8,503,596,384. The average length of stay was 6.1 days. Of these, there were 3.405 deaths (3.39%), and 51% (51,215) were routine discharges. However, a substantial number of patients were discharged to another short-term hospital 3.0% (3,015), another institution like a nursing home or rehabilitation facility, 24.28% (24,385), or home healthcare 17.87% (17,950). Most were Medicare patients, representing 41.18%, with 13.13% on Medicaid, 39.32% on private insurance, and 3.16% uninsured.[1]

It can be surmised that most patients with brain tumors underwent craniotomies as part of their treatment regimen. Using 2014 Medicare Severity Diagnosis Related Groups as a benchmark, an estimated 162,370 craniotomies (MS-DRG 23-27) were performed with a mean cost of $33,023 per event. The National bill (aggregate charges) approached $21 billion with an average length of stay of 7.4 days and in-hospital mortality rate of 6.63%. The 2015 cost, length of stay and in-hospital mortality rates were similar to those of 2015. The total cost of craniotomies vary by geographical location and hospital.[1]

With respect to Intracranial Hemorrhage (ICH), an estimated 123,705 patients were treated for ICH [ICD-9-CM 430, 431, 432.9, 432,432.1]. The reported mean hospital cost per discharge was $27,273, the aggregate charges or National Bill was nearly $14 billion with an average length of stay was 8.3 days and mortality rate of 20.35%. About one quarter experienced a routine discharge with most, 40%, discharged to a nursing home or rehabilitation facility. Over half, 56%, were Medicare patients.[1]

Using MS-DRG codes (64,65,66) an estimated 498,535 intracranial hemorrhage discharges occurred in 2014 costing a mean of $10,537 per incident and a national bill of close to $21 billion. The average length of stay was 4.6 days with an in-hospital mortality rate of 7.12%. The majority of patients did not experience a routine discharge and instead were discharged to another facility, to home health care or short-term hospital 34% vs. 57%, respectively. Most were Medicare patients, around 65%. Previous studies have shown that MS-DRG codes 64 and 65 are consistently among the top conditions and procedures with the highest proportion of ICU utilization.[95]

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