Feasibility of Bundled Payments in Anterior, Middle, and Posterior Cranial Fossa Skull Base Meningioma Surgery: MarketScan Analysis of Health Care Utilization and Outcomes

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■ BACKGROUND: **The aim of our study was to compare the health care utilization and outcomes after surgery for anterior cranial fossa skull base meningioma (AFM), middle cranial fossa skull base meningioma (MFM), and posterior cranial fossa skull base meningioma (PFM) across the United States.**

■ METHODS: **We queried the MarketScan database using *International Classification of Diseases, Ninth Revision* and Current Procedural Terminology 4, from 2000 to 2016. We included adult patients who had at least 24 months of enrollment after the surgical procedure. The outcome of interest was length of hospital stay, disposition, complications, and reoperation after the procedure.**

■ RESULTS: **A cohort of 1191 patients was identified from the database. Less than half of patients (43.66%) were in the AFM cohort, 32.24% were in the MFM cohort, and only 24.1% were in the PFM cohort. Patients who underwent surgery for PFM had longer hospital stay ($P = 0.0009$), high complication rate ($P = 0.0011$), and less likely to be discharged home ($P = 0.0013$) during index hospitalization. There were no differences in overall payments at 12 months and 24 months among the cohorts. There was no significant difference in 90-day median payments among the groups ($66,212 [AFM] vs. $65,602 [MFM] and $71,837 [PFM]; $P = 0.198$). Male gender, commercial insurance (compared with Medicare), and higher comorbidity scores (score 3 compared with score 0) were associated with higher 90-day payments in the PFM cohort.**

■ CONCLUSIONS: **Overall payments (at 12 months and 24 months) and 90-day payments were not different among the cohorts. Patients with PFM had longer hospital stay and higher complication rate and were less likely to be discharged home with higher utilization of outpatient services at 12 months and 24 months.**

INTRODUCTION

Meningioma is the most common benign tumor, accounting for approximately 35.9% of all primary brain tumors, with an average annual age-adjusted incidence rate of 7.62/100,000 population.[1] Because of increasing use of neuroimaging, there has been a 39% increase in the annual case volume of meningioma in the last decade (from 2823 in 2001 to 3923 in 2010).[2] Also, the number of surgeries for meningioma increased by 66% during the same period.[2] The location of these tumors within the intracranial compartment has a significant impact on the clinical outcome and health care utilization after surgical resection.[3] With the advent of stereotactic radiosurgery, multimodality treatment is preferred for tumors that are difficult to access (such as skull base meningioma), thus preserving neurologic functions.[4-10]

Under the Patient Care and Affordable Care Act (Centers for Medicare and Medicaid Services), hospital reimbursement is based on patient satisfaction and hospitals' total performance score to achieve affordable care at a reasonable cost.[11-13] Various alternative payment models based on patient satisfaction and patient-reported outcomes have been proposed to achieve efficient resource utilization.[11,12,14] Bundled payment is 1 such initiative in

Key words
- Anterior
- Bundled payment
- Health care utilization
- Meningioma
- Middle and posterior cranial fossa
- Surgery

Abbreviations and Acronyms
AFM: Anterior cranial fossa skull base meningioma
ER: Emergency room
MFM: Middle cranial fossa skull base meningioma
PFM: Posterior cranial fossa skull base meningioma

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which a finite budget is dispersed to span the health care cost for a procedure over a defined period.[15] This model has been extensively and successfully incorporated in a variety of spinal procedures.[16-20] A bundled payment model has not yet been implemented for cranial procedures by the Centers for Medicare and Medicaid Services (https://innovation.cms.gov/initiatives/bundled-payments/); however, given the current health care situation, these procedures are likely to be included in future. There is a paucity of literature highlighting the usefulness of bundled payment model for cranial procedures,[21] which may be attributed to variability in surgical approaches and techniques related to a variety of intracranial diseases. With increasing diagnosis and subsequent morbidity associated with surgery for skull base meningioma, this disease is likely to have a significant impact on health care utilization related to prolonged hospital stay and long-term follow-up. Our study is the first to provide insight into health care utilization and feasibility of bundled payment for patients with intracranial skull base meningioma, which can be helpful in formulating strategies to reduce health care cost.

In this study, we aimed to compare the health care utilization and outcomes after surgery for anterior cranial fossa skull base meningioma (AFM), middle cranial fossa skull base meningioma (MFM), and posterior cranial fossa skull base meningioma (PFM) across the United States.

METHODS

Data Source

We used the MarketScan data from Truven Health Analytics—IBM Watson Health (Ann Arbor, Michigan, USA). This is a longitudinal claims database that contains 3 insurance types (private, Medicaid, and Medicare supplemental) covering inpatient admissions, outpatient services, and outpatient medications. These data have been extensively used for medical, public health, and epidemiology research for decades[22] and we have described these data in our previous projects.[23,24] We used records of 2000—2016. For this project, we extracted patients who underwent skull base surgeries (anterior fossa, middle fossa, and posterior fossa locations).

Patient Selection

From the inpatient databases, we extracted patients with a primary diagnosis of skull base meningioma with concurrent craniotomy. Obtained cases were divided into 3 skull location groups: anterior, middle, and posterior fossa. We wanted these groups to be exclusive so patients who had tumors in >1 of these locations were excluded. The claim codes for diagnoses and procedures are in **Supplementary Table 1**. Also excluded were patients younger than 18 years. For each patient, the first occurring case satisfying these conditions was flagged as the index hospitalization. We were interested in index hospital, 30-day, 3-month, 6-month, 12-month, and 24-month outcomes; therefore, only patients who had 24 months postsurgery continuous enrollment in their insurance were included in the analysis data set. This exclusion criterion was applied to include only the incidence cohort with no previous cranial surgeries during the 2-year period. We calculated the follow-up time as the difference between the end enrollment date and the index hospitalization discharge date.

Baseline Characteristics

Patient characteristics at the time of index hospitalization were noted as baseline characteristics: age, gender, year of index hospitalization, insurance type (commercial, Medicaid, or Medicare), and comorbidities. The comorbidities were summarized with the Elixhauser Comorbidity Score,[25] computed using an adaptation to *International Classification of Diseases, Ninth Revision, Clinical Modification* and *International Classification of Diseases, Tenth Revision* codes developed by Quan et al.[26] These characteristics were summarized and included in multivariable analyses.

Complications

We considered the following complications: renal, cardiac, general neurosurgical, general neurologic, deep vein thrombosis or pulmonary embolism, pulmonary, infection, wound infection, and pneumonia. We evaluated complications during the index hospitalization and within 30 days after discharge.

Health Care Utilization Outcomes

Health care utilization during the index hospitalization and in the postdischarge period was of interest. For the index hospitalization, resource use outcomes were the length of stay and discharge disposition. The postdischarge period was divided into short-term (30 days) and long-term (3, 6, 12, and 24 months). The short-term outcomes were emergency room (ER) and hospital admissions. For the long-term, we looked at hospital admissions, outpatient services, and medication refills.

Payments

All payments were inflated to 2016 U.S. dollars using the medical component of the consumer price index accessible through the U.S. Bureau of Labor Statistics Web site.[27] We were interested in all the payments associated with the health care utilization described earlier. We looked at inpatient payments (the sum of all hospitalizations), outpatient payments (sum of all outpatient services), medication payments (sum of all prescription medication refills), and the combination of all three. ER services were not included in the summation because they are a subset of the inpatient admissions or outpatient services. Another outcome of interest was the 90-day payment. We calculated it as the summation of all payments from the index hospitalization and all ER and hospital admissions and medications within 90 days after discharge.

Statistical Analysis

We summarized the baseline characteristics and outcomes using means and standard deviations and median and interquartile range, as well as the full range (minimum to maximum) for continuous variables and frequency count and percentage for categorical variables. To perform the patient characteristics comparison and the outcomes unadjusted comparison among the 3 skull location groups, we used the Wilcoxon rank sum test for continuous variables and χ^2 test for categorical variables.[28] Outcomes were further compared in adjusted analyses using multivariable regressions for each outcome accounting for all patient characteristics (gender, Elixhauser Index, and insurance type). We used the linear regression on log-transformed values for continuous outcomes and the logistic regression for

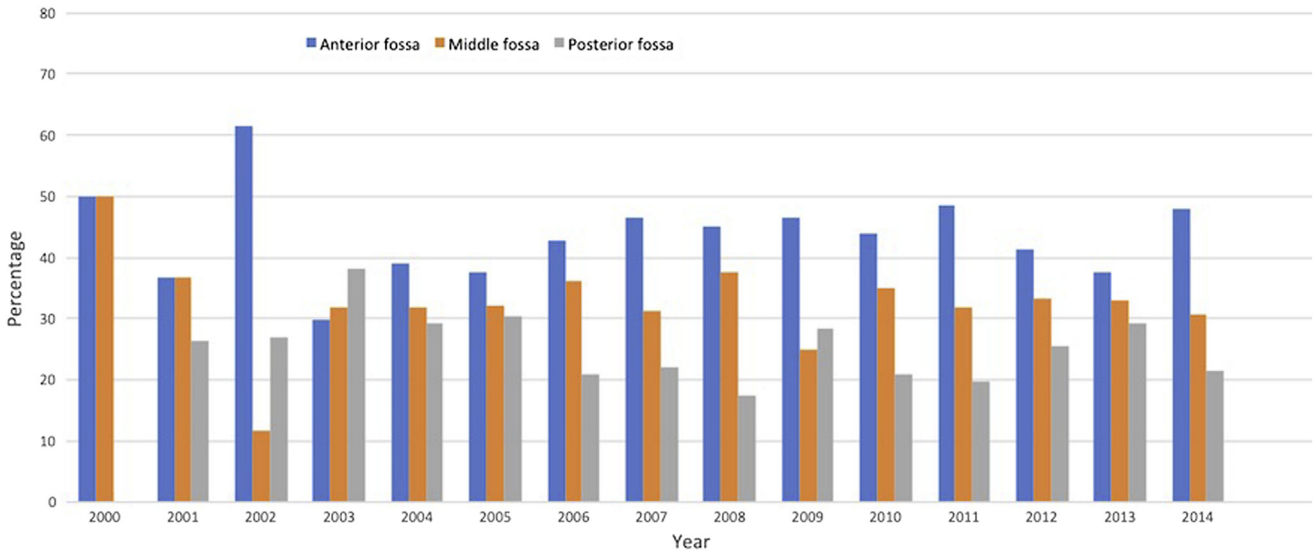

Figure 1. The trends (2000–2014) of craniotomies for anterior, middle, and posterior skull base meningiomas, using MarketScan database.

categorical outcomes. Results were presented in terms of relative risk for continuous variables and odds ratio for categorical variable with associated 95% confidence intervals as a measure of precision. All tests were 2 sided and 0.05 was set as the significance level. We used the software SAS 9.4M5 (SAS Institute, Inc, Cary, North Carolina, USA) for data preprocessing and data analysis.[29]

RESULTS

Patient Demographics

A cohort of 1191 patients who underwent surgery for intracranial skull base meningioma and with >24 months follow-up was identified from the database (Figure 1). Of these meningiomas, 43.66% were confined to the anterior fossa (AFM), 32.24% were

Table 1. Patient Demographics and Characteristics Stratified by Location of Meningioma (>24 Months Follow-Up)

Variables	Combined Cohort (N = 1191)	Group 1: Anterior Fossa (N = 520; 43.66%)	Group 2: Middle Fossa (N = 384; 32.24%)	Group 3: Posterior Fossa (N = 287; 24.1%)	*P* Value
Age (years)					0.586
Mean (standard deviation)	53.2 (11.4)	53.3 (11.2)	52.8 (11.6)	53.4 (11.4)	
Median (interquartile range)	53 (46–60)	54 (46–60)	53 (45–60)	53 (46–61)	
Range, minimum–maximum	18–87	19–87	19–85	18–81	
Gender: female	910 (76.41)	395 (75.96)	294 (76.56)	221 (77)	0.942
Insurance					0.396
Commercial	942 (79.09)	409 (78.65)	309 (80.47)	224 (78.05)	
Medicaid	93 (7.81)	47 (9.04)	28 (7.29)	18 (6.27)	
Medicare	156 (13.1)	64 (12.31)	47 (12.24)	45 (15.68)	
Elixhauser Index					0.391
0	375 (31.49)	165 (31.73)	116 (30.21)	94 (32.75)	
1	366 (30.73)	148 (28.46)	118 (30.73)	100 (34.84)	
2	262 (22)	118 (22.69)	91 (23.7)	53 (18.47)	
≥3	188 (15.79)	89 (17.12)	59 (15.36)	40 (13.94)	

Values are number (%) except where indicated otherwise.

Table 2. Outcome Comparison Among Groups with >24 Months Follow-Up

Variable	Anterior Fossa (N = 520; 43.66%)	Middle Fossa (N = 384; 32.24%)	Posterior Fossa (N = 287; 24.1%)	*P* Value	Cohort (N = 1191; 100%)
Index hospitalization outcomes					
Length of stay, median (IQR)	4 (3—6)	4 (3—6)	5 (3—8)	***0.0009***	4 (3—7)
Prolonged length of stay (>Q3 + 1.5 × IQR), n (%)	54 (10.38)	34 (8.85)	26 (9.06)	0.7003	114 (9.57)
Payment, median (IQR)	54,644 (37,585—83,045)	54,513 (37,472—80,613)	58,841 (39,000—96,603)	0.1628	54,843 (37,765—84,568)
Discharge home, n (%)	441 (84.81)	333 (86.72)	220 (76.66)	***0.0013***	994 (83.46)
Complications, n (%)	157 (30.19)	115 (29.95)	120 (41.81)	***0.0011***	392 (32.91)
30 days postdischarge outcomes					
Emergency room admission, OR (95% CI)	71 (13.65)	40 (10.42)	34 (11.85)	0.3324	145 (12.17)
Hospital readmission, OR (95% CI)	60 (11.54)	40 (10.42)	41 (14.29)	0.2959	141 (11.84)
Complications, OR (95% CI)	92 (17.69)	66 (17.19)	68 (23.69)	0.0636	226 (18.98)
3 months postdischarge outcomes					
Hospital readmissions					
Readmitted, n (%)	88 (16.92)	65 (16.93)	60 (20.91)	0.3087	213 (17.88)
Number of readmissions, median (IQR)	0 (0—0)	0 (0—0)	0 (0—0)	0.257	0 (0—0)
Payments, median (IQR)	21,428 (13,077—40,208)	26,373 (11,188—45,606)	35,433 (12,807—56,206)	0.5003	23,175 (11,970—46,136)
Outpatient services					
Number of services, median (IQR)	20 (8—40)	17 (6—39)	20 (8—51)	0.0427	19 (7—41)
Payments, median (IQR)	3020 (1219—7046)	2482 (786—6568)	3220 (776—8548)	0.0985	2851 (989—7116)
Medication refills					
Number of refills, median (IQR)	18 (3—30)	15 (3—30)	15 (3—30)	0.7403	15 (3—30)
Payments, median (IQR)	668 (31—2055)	523 (40—2110)	493 (41—1951)	0.7852	569 (35—2071)
Overall payments, median (IQR)	5182 (2008—17,083)	5114 (1925—15,346)	5569 (1798—19,201)	0.6836	5251 (1934—17,354)
6 months postdischarge outcomes					
Hospital readmissions					
Admitted, n (%)	106 (20.38)	82 (21.35)	65 (22.65)	0.7518	253 (21.24)
Number of readmissions, median (IQR)	0 (0—0)	0 (0—0)	0 (0—0)	0.6416	0 (0—0)
Payments, median (IQR)	20,549 (11,649—44,171)	23,048 (9924—44,195)	35,208 (14,923—54,945)	0.2535	23,822 (11,649—46,890)
Outpatient services					
Number of services, median (IQR)	37 (17—69)	32 (14—72)	37 (16—82)	0.3764	35 (16—72)
Payments, median (IQR)	6254 (2813—13,738)	5597 (2686—13,964)	5805 (2777—13,959)	0.9268	5923 (2768—13,781)
Medication refills					
Number of refills, median (IQR)	29 (6—59)	27 (9—54)	27 (6—54)	0.7688	27 (6—57)
Payments, median (IQR)	1300 (87—3807)	1111 (111—3958)	962 (134—3866)	0.8352	1147 (98—3900)
Overall payments, median (IQR)	10,758 (4532—31,060)	10,032 (4175—32,140)	11,490 (4528—31,164)	0.9616	10,764 (4466—31,329)
12 months postdischarge outcomes					
Hospital readmissions					
Admitted, n (%)	133 (25.58)	101 (26.3)	72 (25.09)	0.9354	306 (25.69)
Number of readmissions, median (IQR)	0 (0—1)	0 (0—1)	0 (0—1)	0.9061	0 (0—1)

Bold and italic values are significant. Values are number (%) except where indicated otherwise.
IQR, interquartile range; OR, odds ratio; CI, confidence interval.

Continues

Table 2. Continued

Variable	Anterior Fossa (N = 520; 43.66%)	Middle Fossa (N = 384; 32.24%)	Posterior Fossa (N = 287; 24.1%)	*P* Value	Cohort (N = 1191; 100%)
Payments, median (IQR)	23,175 (11,466–49,020)	26,699 (11,117–45,606)	35,364 (14,675–62,724)	0.3495	25,513 (11,754–52,924)
Outpatient services					
Number of services, median (IQR)	61 (33–115)	65 (30–112)	63 (30–134)	0.9043	62 (32–116)
Payments, median (IQR)	10,866 (5622–24,543)	10,477 (4946–27,273)	10,975 (4562–25,299)	0.5706	10,845 (5096–25,284)
Medication refills					
Number of refills, median (IQR)	51 (12–105)	48 (12–102)	45 (12–106)	0.6418	49 (12–105)
Payments, median (IQR)	2410 (260–7237)	2354 (261–8439)	1708 (250–7109)	0.724	2243 (251–7675)
Overall payments, median (IQR)	19,739 (9571–51,303)	20,671 (7562–52,369)	20,902 (6885–50,572)	0.5818	20,495 (8258–52,155)
24 months postdischarge outcomes					
Hospital readmissions					
Admitted, n (%)	166 (31.92)	138 (35.94)	91 (31.71)	0.3737	395 (33.17)
Number of readmissions, median (IQR)	0 (0–1)	0 (0–1)	0 (0–1)	0.2942	0 (0–1)
Payments, median (IQR)	26,001 (13,084–53,772)	30,835 (13,041–62,974)	35,208 (14,426–63,287)	0.5656	29,466 (13,307–59,167)
Outpatient services					
Number of services, median (IQR)	104 (64–185)	112 (60–205)	115 (58–208)	0.7717	109 (61–194)
Payments, median (IQR)	18,369 (9672–39,074)	20,406 (10,069–50,684)	18,731 (8621–41,717)	0.1994	19,025 (9466–42,267)
Medication refills					
Number of refills, median (IQR)	96 (24–203)	93 (26–193)	81 (21–186)	0.5455	92 (24–195)
Payments, median (IQR)	4827 (605–14,979)	4804 (546–15,688)	3272 (438–13,136)	0.4263	4488 (540–14,675)
Overall payments, median (IQR)	37,241 (16,495–78,026)	44,133 (16,486–97,642)	36,048 (14,264–78,415)	0.1305	38,049 (15,900–84,868)

Bold and italic values are significant. Values are number (%) except where indicated otherwise.
IQR, interquartile range; OR, odds ratio; CI, confidence interval.

in the middle fossa (MFM), and only 24.1% were located in the posterior fossa (PFM). Overall, patient median age was 53 years (interquartile range, 46–60 years). Most patients (76.4%) were female, had private insurance (79%), and had an Elixhauser Comorbidity Index of 0–2 (84%). There was no significant difference in terms of age, gender, comorbidity indices, and type of insurance among the groups (Table 1).

Outcomes and Complications at Index Hospitalization and 30-Days After Discharge

Patients who underwent surgery for PFM had longer hospital stay ($P = 0.0009$) and higher complication rate ($P = 0.0011$) and were less likely to be discharged home ($P = 0.0013$) during index hospitalization. Most patients in all cohorts were discharged home (76.6% of patients with PFM, 84.8% with AFM, and 86.7% with MFM). However, no difference was noted based on number of patients who had prolonged length of hospital stay (>3 quartile) after surgery (10.38% [AFM], 8.85% [MFM], 9.06% [PFM]). Also, no difference was noted for median index hospitalization payments among the cohorts (AFM, $54,644; MFM, $54,513; PFM, $58,841). Patients who underwent surgery for PFM were likely to have hospital readmission within 30 days after the procedure (14.29%) compared with those with AFM (11.54%) or MFM (10.42%) ($P = 0.2959$); however, this difference was not observed on adjusted analysis ($P = 0.1922$). There was no difference in ER admission rates and complications at 30 days after discharge among the groups ($P = 0.33$ and 0.06, respectively). However, on adjusted analysis, patients in PFM cohort showed higher complication rates at 30 days compared with those with AFM ($P = 0.0387$, Tables 2 and 3).

Outcomes at 3, 6, 12, and 24 Months After Discharge

Patients who underwent surgery for PFM incurred higher outpatient services at 3 months ($P = 0.04$) and 6 months (<0.0001) after discharge compared with those with AFM. Similarly, patients with PFM were likely to have higher hospital readmissions at 3 months compared with those with AFM (relative risk, 1.46; 95% confidence interval, 1.102–1.936). There were no differences in overall payments at 3 months (median AFM, $5182; MFM, $5114; PFM, $5569) and 6 months (AFM, $10,758; MFM, $10,032; PFM, $11,490) among the cohorts.

Patients with MFM and PFM incurred higher outpatient services with no differences in corresponding payments compared with those with AFM at 12 months ($P < 0.0001$) and 24 months

Table 3. Outcome Adjusted Comparison* Among Groups with >24 Months Follow-Up

Variable	Anterior Fossa (N = 520; 43.66%)	Middle Fossa (N = 384; 32.24%)	Posterior Fossa (N = 287; 24.1%)	*P* Value
Index hospitalization outcomes				
Length of stay, RR (95% CI)	Reference	0.965 (0.885–1.052)	**1.204 (1.095–1.323)**	***<0.0001***
Prolonged length of stay (>Q3 + 1.5 × IQR)	Reference	0.863 (0.542–1.375)	0.97 (0.583–1.612)	0.8204
Payment, RR (95% CI)	Reference	0.997 (0.898–1.106)	**1.149 (1.025–1.288)**	***0.0327***
Discharge home, OR (95% CI)	Reference	1.128 (0.765–1.665)	**0.54 (0.37–0.787)**	***0.0006***
Complications, n (%)	Reference	0.999 (0.744–1.341)	**1.789 (1.313–2.437)**	***0.0003***
30 days postdischarge outcomes				
Emergency room admission, OR (95% CI)	Reference	0.738 (0.484–1.123)	0.922 (0.589–1.443)	0.3607
Hospital readmission, OR (95% CI)	Reference	0.893 (0.583–1.368)	1.356 (0.882–2.086)	0.1922
Complications, OR (95% CI)	Reference	0.977 (0.686–1.392)	**1.519 (1.058–2.181)**	***0.0387***
3 months postdischarge outcomes				
Hospital readmissions				
Readmitted, n (%)	Reference	1.004 (0.705–1.431)	1.368 (0.946–1.98)	0.1937
Number of readmissions, median (IQR)	Reference	1.05 (0.794–1.39)	**1.46 (1.102–1.936)**	***0.0213***
Payments, median (IQR)	Reference	1.027 (0.748–1.41)	1.187 (0.857–1.644)	0.5631
Outpatient services				
Number of services, median (IQR)	Reference	0.906 (0.884–0.929)	**1.13 (1.102–1.16)**	***<0.0001***
Payments, median (IQR)	Reference	0.798 (0.643–0.991)	0.869 (0.686–1.1)	0.1145
Medication refills				
Number of refills, median (IQR)	Reference	0.994 (0.966–1.023)	1.013 (0.982–1.046)	0.524
Payments, median (IQR)	Reference	0.865 (0.69–1.084)	0.913 (0.712–1.171)	0.4383
Overall payments, median (IQR)	Reference	0.917 (0.736–1.143)	1.034 (0.812–1.316)	0.6132
6 months postdischarge outcomes				
Hospital readmissions				
Admitted, n (%)	Reference	1.062 (0.766–1.472)	1.187 (0.835–1.689)	0.6335
Number of readmissions, median (IQR)	Reference	1.137 (0.893–1.448)	1.253 (0.967–1.623)	0.2207
Payments, median (IQR)	Reference	1.012 (0.75–1.367)	1.198 (0.867–1.655)	0.5013
Outpatient services				
Number of services, median (IQR)	Reference	**0.975 (0.957–0.993)**	**1.105 (1.084–1.127)**	***<0.0001***
Payments, median (IQR)	Reference	0.973 (0.806–1.174)	0.873 (0.71–1.072)	0.42
Medication refills				
Number of refills, median (IQR)	Reference	1.017 (0.996–1.038)	0.997 (0.974–1.02)	0.1917
Payments, median (IQR)	Reference	0.894 (0.712–1.124)	0.881 (0.686–1.133)	0.5057
Overall payments, median (IQR)	Reference	1.009 (0.831–1.225)	0.941 (0.761–1.164)	0.8088
12 months postdischarge outcomes				
Hospital readmissions				
Admitted, n (%)	Reference	1.044 (0.772–1.413)	1.005 (0.719–1.404)	0.9577
Number of radmissions, median (IQR)	Reference	1.223 (0.996–1.502)	1.165 (0.927–1.466)	0.135

Bold and italics *P* values are significant. Bold RR or OR indicate significant comparison.
IQR, interquartile range; RR, relative risk; OR, odds ratio; CI, confidence interval.
*Adjusted comparisons are obtained from linear contrasts obtained from multivariable regression models, which include covariates gender, age, Elixhauser Index and insurance. Continues

Table 3. Continued

Variable	Anterior Fossa (N = 520; 43.66%)	Middle Fossa (N = 384; 32.24%)	Posterior Fossa (N = 287; 24.1%)	*P* Value
Payments, median (IQR)	Reference	1.016 (0.766–1.346)	1.231 (0.9–1.683)	0.3879
Outpatient services				
Number of services, median (IQR)	Reference	**1.018 (1.004–1.033)**	**1.102 (1.085–1.119)**	***<0.0001***
Payments, median (IQR)	Reference	1.055 (0.894–1.245)	0.91 (0.759–1.091)	0.3185
Medication refills				
Number of refills, median (IQR)	Reference	1.019 (1.003–1.035)	**0.964 (0.948–0.981)**	***<0.0001***
Payments, median (IQR)	Reference	0.901 (0.712–1.141)	0.86 (0.663–1.114)	0.4688
Overall payments, median (IQR)	Reference	1.007 (0.847–1.198)	0.899 (0.743–1.088)	0.4715
24 months postdischarge outcomes				
Hospital readmissions				
Admitted, n (%)	Reference	1.208 (0.912–1.601)	1.012 (0.74–1.385)	0.3721
Number of readmissions, median (IQR)	Reference	**1.353 (1.145–1.6)**	1.129 (0.93–1.37)	***0.0018***
Payments, median (IQR)	Reference	1.098 (0.85–1.42)	1.206 (0.901–1.614)	0.4398
Outpatient services				
Number of services, median (IQR)	Reference	**1.042 (1.031–1.053)**	**1.087 (1.074–1.1)**	***<0.0001***
Payments, median (IQR)	Reference	1.12 (0.966–1.298)	0.974 (0.829–1.145)	0.1989
Medication refills				
Number of refills, median (IQR)	Reference	**1.042 (1.031–1.054)**	**0.959 (0.947–0.971)**	***<0.0001***
Payments, median (IQR)	Reference	0.914 (0.722–1.157)	0.826 (0.638–1.071)	0.3461
Overall payments, median (IQR)		1.098 (0.94–1.282)	0.933 (0.787–1.106)	0.1953a

Bold and italics *P* values are significant. Bold RR or OR indicate significant comparison.
IQR, interquartile range; RR, relative risk; OR, odds ratio; CI, confidence interval.
*Adjusted comparisons are obtained from linear contrasts obtained from multivariable regression models, which include covariates gender, age, Elixhauser Index and insurance.

follow-up ($P < 0.0001$), whereas patients with AFM incurred higher medications refills compared with those with PFM at 12 and 24 months. At 24 months, patients with MFM had higher hospital readmissions compared with those with AFM ($P = 0.0018$). As mentioned earlier, there were no differences in overall payments at 12 months (AFM, $19,739; MFM, $20,671; PFM, $20,902) and 24 months (AFM, $37,241; MFM, $44,133; PFM, $36,048) among the cohorts (Tables 2 and 3, Figure 2).

Ninety-Day Payments and Factors Predicting These Payments

There was no significant difference in 90-day median payments among the groups ($66,212 [AFM] vs. $ 65,602 [MFM] and $71,837 [PFM]; $P = 0.198$). Of these 90-day payments, median total payments at index hospitalization were not significantly different among the groups, with maximum for the PFM group: $54,644 (AFM) versus $54,513 (MFM) and $58,841 (PFM) ($P = 0.628$). However, there were significant differences only in the physician payments across the cohorts with maximum for the MFM ($7336) and least for the ACM cohort ($6469). No differences were noted among the groups for 90-day postdischarge payments ($P > 0.05$). Median total payments, readmission payments, outpatient services payment, and medication payment were similar among the groups ($P = 0.66$, 0.30, 0.08, and 0.71, respectively) (Table 4).

Male gender, commercial insurance (compared with Medicare), and higher comorbidity scores (score 3 compared with score 0) were associated with higher 90-day payments in patients undergoing surgery for PFM. Similarly, commercial insurance (compared with Medicaid) and higher comorbidity scores (score 1 and 3 compared with score 0) were associated with higher 90-day payments in patients with MFM, whereas only higher comorbidity scores (score 3 compared with score 0) were associated with higher bundled payment in patients with AFM. We also found that patients who were discharged home had 47%, 32%, and 54% lower payments in the AFM, MFM, and PFM groups, respectively, compared with those who were discharged to other locations (rehabilitation, skilled nursing facility, or long-term care) (Table 5).

DISCUSSION

Patients with skull base meningioma pose significant challenges to treating physicians because of proximity of these lesions to critical neurovascular structures, morbidity associated with surgical approaches, and the benign nature of these lesions requiring

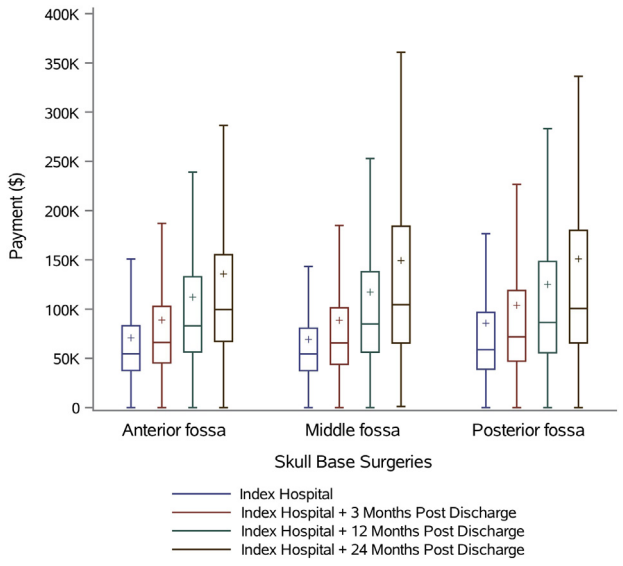

Figure 2. Payments during index hospitalization, index hospitalization + 3 months, 12 months, and 24 months after craniotomies for anterior, middle, and posterior skull base meningiomas, using MarketScan database.

long follow-up. Therefore, the concept of "do no harm" most aptly applies to these benign tumors, resulting in emergence of a multimodality approach to treat these tumors with safe surgical resection and radiosurgery.[7-9] Also, the complexity of neurosurgical procedure, postoperative critical care, and requirement for long-term follow-up contribute to the health care utilization associated with these procedures.

In our study, we found that patients with PFM had longer hospital stay, higher complication rate, and less likely to be discharged home with higher utilization of outpatient services at 12 months and 24 months, compared with those with AFM. Posterior fossa meningiomas are challenging lesions to resect and associated with high morbidity and mortality.[3,6,30,31] Roberti et al.[31] reported an overall complication rate of 41% in their large retrospective series of 161 patients. In concordance, overall complications after resection of PFM during index hospitalization were 41.7% in our study.

We also found that patients with PFM incurred higher outpatient services at 3, 6, 12, and 24 months after discharge compared with those with AFM. However, there were no differences in overall payments at 3 months (AFM, $5182; MFM, $5114; PFM, $5569), 6 months (AFM, $10,758; MFM, $10,032; PFM, $11,490) 12 months (AFM, $19,739; MFM, $20,671; PFM, $20,902) and 24 months (AFM, $37,241; MFM, $44,133; PFM, $36,048) among the cohorts. Similarly, Connolly et al.[21] reported no difference in 90-day postdischarge payments in patients undergoing endoscopic ($2000) versus microscopic ($1700) surgeries for colloid cyst using the MarketScan database.

As expected, patients with PFM tend to incur higher utilization of health care resources in the postoperative period because of increased morbidity associated with resection of these lesions. However, we did not see any difference in overall payments at all time points (including 90 days), which reflect that the increased postoperative morbidities in patients with PFM were not associated with increased health care payments at long-term follow-up. However, patients who were discharged home had lower payments across all cohorts compared with those who were discharged to other facilities. This finding points toward the current payment model in this patient population using MarketScan database. There are certain caveats of using administrative databases such as coding errors, underreporting, nonavailability of clinical data points (e.g., tumor size or involvement of critical neurovascular structures), and so on. Also, differences in the utilization of outpatient services and other health care resource, although statistically significant, may not be clinically relevant, such as 20 times outpatient services in patients with PFM compared with 17 times in patients with MFM at 3 months. Therefore, in light of these findings, results need to be cautiously interpreted. Nevertheless, these findings support the feasibility of a 90-day bundled payment model in this patient population, which is unlikely to be different from the current payment model in terms of overall reimbursement.

Ninety-Day Payments, Factors Predicting 90-Day Payment, and Future Direction

In our study, we found no significant difference in 90-day median payments among the groups (AFM, $66,212; MFM, $65,602; and PFM, $71,837). Similarly, we did not find differences in overall payments at 3, 6, 12, and 24 months follow-up across the cohorts. Although patients with PFM had higher complication rate during index hospitalization and were less likely to be discharged home with higher utilization of outpatient services at 12 months and 24 months, these factors had no impact on overall payments during these periods. Based on these results, we believe that bundled payment can be a potential payment model strategy in patients with skull base meningioma, despite differences in complication rate and clinical outcomes during index hospitalization.

Factors such as male gender and higher comorbidities had an impact on 90-day payment in patients undergoing surgery for PFM. Higher comorbidity index had an impact on payment across all cohorts. Ambekar et al.[2] using the Nationwide Inpatient Sample database showed that male patients with high comorbidity index (Charlson Comorbidity Index $\geq$2) had higher odds of adverse outcomes at discharge and mortality compared with those with low comorbidity index (Charlson Comorbidity Index 0 and 1) after surgery for intracranial meningioma. These factors can be integrated while formulating strategies for bundled payment model to reduce health care cost in patients with skull base meningioma.

Strengths and Limitations

Our study provides insight into the feasibility of bundled payment model in patients after surgery for skull base meningioma, using the MarketScan database. This database provide longitudinal follow-up of patients with utilization of health care resources such as outpatient visits, medication refills, and associated payments by the health care insurance. Therefore, this database helps in

Table 4. 90-Day Payments Across Different Groups for 24 Months Follow-Up

Variables	All Patients (N = 1188)			*P* Value
	Group 1: Anterior Fossa (N = 520; 43.66%)	Group 2: Middle Fossa (N = 384; 32.24%)	Group 3: Posterior Fossa (N = 287; 24.1%)	
90-day payments				0.198
Mean (SD)	88,689 (90,423)	88,256 (85,612)	103,774 (108,751)	
Median (Q1—Q3)	66,212 (45,229—102,797)	65,602 (43,808—101,122)	71,837 (47,132—116,424)	
Min—max	0—971,852	0—1,054,319	0—858,637	
Index hospitalization				
Total payment				0.628
Mean (SD)	70,795 (67,766)	69,239 (55,003)	85,746 (91,238)	
Median (Q1—Q3)	54,644 (37,585—83,045)	54,513 (37,472—80,613)	58,841 (39,000—96,603)	
Min—max	0—786,554	0—454,125	0—682,928	
Physician payment				***0.0008***
Mean (SD)	7677 (7684)	9911 (10759)	9817 (11403)	
Median (Q1—Q3)	6469 (3976—9603)	7336 (4943—11,777)	7100 (4421—12,171)	
Min—max	0—78,873	0—102,904	0—105,252	
Hospital payment				0.506
Mean (SD)	43,251 (51,696)	39,264 (39,043)	49,070 (62,863)	
Median (Q1—Q3)	31,104 (18,646—49,837)	29,162 (17,181—47,859)	28,908 (17,152—56,879)	
Min—max	0—640,184	0—339,231	0—511,358	
90 days after discharge				
Total payment				0.663
Mean (SD)	17,894 (40,062)	19,018 (54,702)	18,028 (30,034)	
Median (Q1—Q3)	5124 (1961—16,459)	4844 (1919—14,777)	5383 (1798—18,502)	
Min—max	0—481,201	0—891,507	0—222,424	
Readmission payment				0.3016
Mean (SD)	6988 (29,911)	8131 (47,471)	8483 (24,005)	
Median (Q1—Q3)	0 (0—0)	0 (0—0)	0 (0—0)	
Min—max	0—424,194	0—851,957	0—196,800	
Outpatient services payment				0.0806
Mean (SD)	9091 (22,615)	9276 (23,854)	7932 (14,799)	
Median (Q1—Q3)	3020 (1191—6981)	2446 (786—6374)	3220 (776—8371)	
Min—max	0—358,220	0—201,989	0—148,387	
Medication payment				0.7094
Mean (SD)	1815 (3869)	1611 (2610)	1613 (3008)	
Median (Q1—Q3)	664 (29—2001)	518 (40—2071)	479 (39—1883)	
Min—max	0—53,781	0—18,262	0—23,739	

Bold and italics values are significant.
SD, standard deviation; Q, quartile; min—max, minimum—maximum.

Table 5. Multivariate for 90-days Payment

Cofactor	Category	Group 1 Anterior Fossa N = 520 (43.66%)	Group 2 Middle Fossa N = 384 (32.24%)	Group 3 Posterior Fossa N = 287 (24.1%)
Age	+ 10 year	1.112 (0.997, 1.24)	0.966 (0.87, 1.074)	1.077 (0.93, 1.249)
Gender	Female vs Male	0.897 (0.739, 1.088)	0.815 (0.662, 1.004)	**0.655 (0.51, 0.842)**
Insurance type	Medicaid vs Commercial	1.011 (0.745, 1.372)	**0.49 (0.26, 0.924)**	0.65 (0.333, 1.269)
	Medicare vs Commercial	0.794 (0.569, 1.108)	0.792 (0.524, 1.198)	**0.558 (0.331, 0.939)**
Elixhauser Score	Score 1 vs 0	1.2 (0.931, 1.547)	**1.343 (1.024, 1.762)**	0.997 (0.713, 1.393)
	Score 2 vs 0	1.266 (0.977, 1.639)	1.15 (0.845, 1.564)	1.328 (0.939, 1.878)
	Score 3 vs 0	**1.466 (1.127, 1.905)**	**1.805 (1.355, 2.404)**	**1.547 (1.093, 2.189)**
Discharge	Home vs others	**0.538 (0.449, 0.646)**	**0.68 (0.543, 0.852)**	**0.466 (0.369, 0.588)**

Bold values are significant.

understanding the overall health care utilization over an extended period after a surgical procedure.

Although we acknowledge that our cohort size is small with noninclusion of patients with severe postoperative complications, leading to mortality and underestimation of complication/30-day readmission rates (because of inclusion of patients with available 24 months of follow-up), our study is the first to provide the feasibility of bundled payment model and factors predicting it, in patients with skull base meningioma. Our study will provide a reference for future studies related to bundled payment in this patient population. Other limitations of using the MarketScan database include lack of clinical and imaging data for an individual patient, which was used to guide the clinical decision making, surgical strategies, and so on. Also, selection bias, potential for coding errors (*International Classification of Diseases*/Current Procedural Terminology billing codes), lack of quality of life data, and complications specific to surgical procedure and individual patient cannot be extrapolated using this database. Therefore, results of the study need to be interpreted cautiously in light of these limitations.

CONCLUSIONS

Overall (at 12 months and 24 months) and 90-day payments were not significantly different among the cohorts. Patients with PFM had longer hospital stay and higher complication rate and were less likely to be discharged home with higher utilization of outpatient services at 12 and 24 months. Male gender, commercial insurance, and higher comorbidity scores were associated with higher 90-day payments in patients with PFM. These factors can be considered while creating bundled payment models, so as to reduce health care costs in patients undergoing surgery for intracranial meningioma.

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Supplementary Table 1. *International Classification of Diseases, Ninth Revision/Tenth Revision* Codes Used for Data Extraction

Diagnosis	*International Classification of Diseases, Ninth Revision* Code	*International Classification of Diseases, Tenth Revision* Code	Current Procedural Terminology Code
Benign neoplasm of cerebral meninges	225.2	D32.0, D32.9	
Malignant neoplasm of cerebral meninges	192.1	C70.0, C70.9	
Neoplasm of uncertain behavior of meninges	237.6	D42.0, D42.9	
Procedure			
Craniotomy for anterior skull base meningioma (group 1)			(61580, 61581, 61582, 61583, 61584, 61585, 61586) and (61600, 61601)
Craniotomy for middle skull base meningioma (group 2)			(61590, 61591, 61592) and (61605, 61606, 61607, 61608)
Craniotomy for posterior skull base meningioma (group 3)			(61595, 61596, 61597, 61598, 61520, 61526) and (61615, 61616)