Economics of the Management of Craniospinal Chordoma and Chondrosarcoma and the Feasibility of the Bundled Payment Model

Zaid Aljuboori (zaid.aljuboori@yahoo.com)
University of Louisville https://orcid.org/0000-0002-3278-4749

Beatrice Ugiliweneza
University of Louisville

Dengzhi Wang
University of Louisville

Norberto Andaluz
University of Louisville

Maxwell Boakye
University of Louisville

Brian Williams
University of Louisville

Research article

Keywords: Chordoma, Chondrosarcoma, Bundled Payment, Clivus, Spine.

Posted Date: March 31st, 2020

DOI: https://doi.org/10.21203/rs.2.21490/v2

Version of Record: A version of this preprint was published on August 21st, 2020. See the published version at https://doi.org/10.1186/s12883-020-01850-w.

Abstract

Background Healthcare expenditures are continuously rising in the United States. The Centers for Medicare and Medicaid Services (CMS) created a new reimbursement model called the “Bundled Payment for Care Improvement (BPCI)”. This model reimburses providers a predetermined payment in advance to cover all possible services delivered to patients within a certain time window. Chordoma and Chondrosarcoma are locally aggressive malignant primary bony tumors. Treatment includes surgical resection and radiotherapy with substantial risk for recurrence which necessitates monitoring and further treatment. We assess the BPCI model in complex neurosurgical diseases. Methods We obtained data from the United States MarketScan database. Patients were identified patients using the International Classification of Diseases 10 codes. Results A total of 2041 patients were included. 1412 patients had cranial, 343 patients had a mobile spine, and 286 patients had sacrococcygeal chordoma and chondrosarcoma. For Index hospitalization, the median length of stay (days) was 4, 6, and 7, mean total payments were ($58,130), ($84,854), and ($82,440), and complication rates were 30%, 35%, and 43% for groups 1, 2, and 3, respectively. The payments during the first 6 months after discharge were comparable to the amounts reimbursed during the index hospitalization for all groups. Conclusion The management of craniospinal chordoma and chondrosarcoma is costly and sustained over time. The success of BPCI requires a joint effort between insurers and hospitals. It should consider patients’ comorbidities, the complexity of the disease. Finally, adoption of quality improvement programs by hospitals can help with cost reduction.

Background

The continuous rise in healthcare expenditures in the United States represents a dilemma to policy makers, insurers, and patients.[1] Under the current fee-for-service (FFS) system, healthcare providers are reimbursed based on the volume of services performed. This system has been criticized on the basis of rewarding providers for increasing the volume of services, not necessarily the quality of care. [2] For example, there is evidence that colonoscopy for colon cancer screening is being done in increased frequency than recommended.[3] To address that, multiple initiatives have been proposed to reduce the cost and increase the quality of care. The Centers for Medicare and Medicaid Services (CMS) have been experimenting with new reimbursement model called the “Bundled Payment for Care Improvement (BPCI)” since 2013. Under this new system, the insurer only pays a pre-specified bundled payment (BP) value in advance to cover all possible services rendered to patients within a specified time window around the treatment, including eventual complications. The payments are calculated using historical financial data.[4] The BPCI initiative involves models 1,2,3 & 4 as a progressive rollout of the plan. Each one of these models has its own definition of the “episode of care”.

In Model 2, the episode includes the inpatient stay in an acute care hospital plus the post-acute care and all related services up to 90 days after hospital discharge.

In contrast to the FFS system, where the insurer reimburses the cost of each test, procedure, hospital stay, etc., including those incurred in case of complications and readmissions.

Chordoma and Chondrosarcoma (CC) are relatively rare primary bony tumors. They are slow growing and malignant tumors. Chordoma originates from the remnants of the notochord and it almost always located along the neuroaxis. It can affect areas anywhere from the clivus to the sacrum. Chondrosarcoma is mesenchymal in origin and characterized by formation of cartilage matrix.[5],[6] To date there are no reports in the literature that link the clinical and financial characteristics of the management of chordoma and chondrosarcoma to the potential feasibility of BPCI model.

We report the analyses of data obtained from the MarketScan research database regarding the reimbursements of the management of craniospinal chordoma and chondrosarcoma up to 12 months after index hospitalization. In addition, we discuss the feasibility of the BPCI model considering the results of our analyses.

Methods

Data source

We obtained the data for this study from the Truven Health MarketScan Databases with permission to use. MarketScan is a healthcare research database with de-identified medical records of more than 250 million patients, including inpatient, outpatient and prescription data, with diagnoses and procedures, insurer, and patient payment information.[7] MarketScan contains multiple tables linked with a unique patient identification number, representing the patients' trajectories through the healthcare system. So, it can used to study patient's healthcare utilization longitudinally. For this study, we used the inpatient, outpatient, and medication tables for the years 2000–2015.

Cohort selection

We extracted patients with chordoma/chondrosarcoma from inpatient admission table using the International Classification of Disease, 9th Revision (ICD-9) codes 170.0, 160.2, 143.0, 170.1 and 10th Revision (ICD-10) codes C41.0, C31.0, C03.0, C41.1 for chordoma of skull and face, ICD-9 code 170.2 and ICD-10 code C41.2 for chordoma of vertebral column, ICD-9 170.6 ICD-10 C41.4 for chordoma of sacrum/coccyx. For each patient, the first occurring hospitalization was considered the index hospitalization. Pre-diagnosis lookback time was calculated as the difference between and the beginning enrollment date and the date of the index hospitalization admission. Post-diagnosis follow-up time was calculated as the difference between the date of the index hospitalization discharge and end enrollment date. Patients with less than 12 months follow-up time, or with less than 3 months lookback time, or under 18 years old were excluded.

Patient characteristics

Baseline demographics, age, gender, insurance type (commercial, Medicaid, Medicare) and comorbidities, were summarized at the index hospitalization. Comorbidities were measured with the Elixhauser comorbidity score [8] using ICD-9-CM and ICD-10 codes developed by Quan et al.[9] The following comorbidities were detected from 3 month before index admission to the index discharge: tobacco use, osteoporosis, hypertension, congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), myocardial infarction (MI), diabetes, obesity.

Outcomes

The outcomes of interest were index hospitalization length of stay, total payment, discharge disposition, complications. For post-discharge healthcare use and payment, we were interested in 30 days, 3 months, 6 months and 12 months inpatient admission, outpatient service and medication refills. The bundle payments were calculated as the payments accumulated from the index hospitalization admission to 90 days of post discharge date. All payments were inflated to 2016 US dollars using the medical component of the consumer price index accessible through United States Bureau of Labor Statistics website.[7, 10] Complications were flagged by the presence of the following events on the index complication claim: renal, cardiac, nervous system complication, cerebrovascular disease deep vein thrombosis or pulmonary embolism, pulmonary, infection, pneumonia and wound.

Statistical analysis

Continuous variables were summarized by means with standard deviations, median with interquartile and full ranges (minimum - maximum); categorical variables were summarized by counts and percentages. Continuous outcomes were compared by nonparametric Wilcoxson rank sum test; categorical outcomes were compared among groups by Chi-squared test. Adjusted group comparisons of healthcare use and payment are obtained from linear contrasts of multivariable regression models which includes covariates age, gender, Elixhauser index and insurance, in addition to group. Odds ratios are obtained for the demographic variables on the 90 days bundle payment for each group from multilinear regression. All tests were 2-sided with a significance level of 0.05. Statistical data analysis was performed in SAS 9.4 (SAS Institute, Inc, Cary, NC).

Results

Demographics

A total of 2041 patients were included. Of those patients 69% (N=1214) had cranial, 16.9% (N=297) had mobile spine, and 14% (N=246) had sacrococcygeal chordoma and chondrosarcoma [Fig.1]. The mean age was 57.4, 49.5, and 47.9 years for the cranial, mobile spine, and sacrococcygeal groups, respectively (P <.001). Females represented 43%, 48%, and 44% of the cranial, mobile spine, and sacrococcygeal groups, respectively. Of the cranial group, 60%, 12%, and 28% had commercial, Medicaid, and Medicare insurance, respectively. Of the mobile spine group, 68%, 14%, and 17% had commercial, Medicaid, and

Medicare insurance, respectively. Of the sacrococcygeal group, 73%, 12%, and 14% had commercial, Medicaid, and Medicare insurance, respectively. See [Tables 1 and 2] for additional details.

Index hospitalization and 30 days post discharge outcomes

Index hospitalization, the median length of stay (days) was 4, 6, and 7 for groups 1, 2, and 3 respectively (P<.001). The mean payments were ($58,130), ($84,854), and ($82,440), for groups 1, 2, and 3 respectively (P=.02). The complication rates were 30%, 35%, and 43% for groups 1, 2, and 3 respectively (P<.001).

Thirty days post discharge, the emergency department admissions were 10%, 12%, and 18% for groups 1, 2, and 3, respectively (P=.001). The hospital readmissions were 10%, 23%, and 30% for groups 1, 2, and 3, respectively (p <.001). The complication rates were 18%, 24%, 30% for groups 1, 2, and 3, respectively (P <.001) [Table 3].

Three- and twelve-months post discharge outcomes

Three months post-discharge, the hospital readmission rates were 21%, 38%, and 45% for groups 1, 2, and 3, respectively (P <.001). There was no difference in the number of outpatient services and medications refill among the groups. The overall median payments for this period were ($27,590), ($25,968), and ($35,819), for groups 1, 2, and 3, respectively (P=.04) [Table 3].

Twelve months post-discharge, the hospital readmission rates were 44%, 53%, and 65% for groups 1, 2, and 3, respectively (P<.001). The median number of outpatient services rendered was 166, 165, and 211, for groups 1, 2, and 3, respectively (P <.001). The overall median payments for this period were ($72,294), ($76,827), and ($101,474), for groups 1, 2, and 3, respectively (P <.001) [Table 3], [Fig2.]. The bundled payment for the index hospitalization and 90 days post discharge see [Table 4], [Fig.3].

Adjusted comparison among groups

Using the cranial group (1) as a reference, the index hospitalization of the combined spinal group (groups 2, and 3) had increased length of stay (RR1.2, 1.6, P < .001), a higher complications rate (RR 1.1, 1.8, P<.001), and decreased rate of discharge to home (0RR0.3, 0.25, P<.001). Thirty days post-discharge, the combined spinal group (groups 2 and 3) had a higher ED admission (OR 1.08, 1.7, P=.01), hospital readmission (OR 2.3, 3.1, P <.001), and complications rate (OR 1.5, 2.4, P <.001). Three months post-discharge, the combined spinal group (groups 2, and 3) had a higher hospital admission (OR 2, 2.6, P <.001), and a decreased use of outpatient services (RR 0.8, 0.9, P <.001). The twelve months post-discharge, the combined spinal group (groups 2, and 3) had a higher hospital readmission (OR 1.2, 2.1, P <.001), higher medication refill (RR 1.03, 1.1, P <.001), and a had higher overall payment (RR 1.02, 1.2, P=.02).

Ninety days multivariate analysis

Increased age by 10 years increment was associated with a decreased payment for groups 1, 2, and 3, (OR 0.9, 0.89, and 0.88). Medicaid insurance was associated with a decreased payment for groups 1, 2, and 3 (OR 0.5, 0.3, and 0.47) in comparison to commercial insurance. Medicare was associated with a decreased payment only for group 1 (OR 0.77). EI of 2 was associated with a higher payment for groups 1 and 2 (OR 1.1 and 1.5), while EI of 3 was associated with a higher payment for groups 1, 2, and 3 (OR 1.4, 1.5, 1.4) [Table 5].

Discussion

Chordoma and chondrosarcoma of the craniospinal axis are challenging neurosurgical conditions[6]. The management paradigm includes maximum safe surgical resection and radiotherapy.[11] The treatment of these conditions can be costly because of the multitude of services required. For example, the treatment of spinal chordoma generally requires a complex spine procedure such as en-bloc surgical excision and multilevel instrumented fusion.[5, 12] This generally is associated with increased length of stay, need for rehabilitation, complications, risk for emergency department visits, hospital readmission, need for pain prescription refills, and cost.[5, 11, 13] Both diseases have high risk for recurrence (~ 57% for cranial and 27% for spinal disease) which may necessitate further treatment.[12, 14-16] These factors make these two conditions valuable to explore the cost and patterns of expenditure over time and the feasibility of adopting the BPCI model for reimbursement.

Our analyses showed that spinal CC patients had increased length of stay and complications rate, which was associated with higher median payment for the index hospitalization in comparison to the cranial group. This could be related to surgical pain and the presence of surgical drains which is common for complex spine surgery, which should be considered when planning the bundled payments for cranial and spinal patients. About 90% of the index hospitalization payments were hospital payments and the remaining 10% were physicians' payment which was not different among the 3 groups. The length of stay has been linked before to increased costs.[17]

Ninety days post-discharge period, the readmission rates were higher for spinal CC (group 2, 38% and group 3, 45%) in comparison to cranial CC (21%), which was associated with higher median payments ($40,227 and $42,242 for group 2 and 3 vs $24,116 for group 1). The higher readmission rates for the mobile spine and sacral groups could have been due to pain or wound problems when compared to the cranial group. Fry et al. reported a 90 days readmission rate of 25% after elective craniotomy for a mass lesion[18], while Lau et al. reported a 90 days readmission rate of 13 % and 20% after surgery for spinal chordoma and chondrosarcoma, respectively. The difference between our study and Lau et al, their reported rate could have been due to a smaller sample size (23 chordomas, 10 chondrosarcomas). Also, they reported a mean direct hospital cost of ($65,413) and ($59,113) for spinal chordoma and chondrosarcoma, respectively. This was higher than the cost in our study (mean cost for hospital payment $50,524).[19] The observed difference can be due to a difference in data capture, since our cost

data is based of insurer reimbursement to hospital claims, while their cost data was retrieved directly from hospital records. One of reasons for the aforementioned comparison between the cranial and spinal CC is to highlight the fact that disease location should be considered in calculating the bundled payment.

Jain et al. reported that back pain, leg pain, wound problems, cardiorespiratory complaints, gastrointestinal complaints, deep venous thrombosis, and systemic infections were the most common causes for ED visit and hospital readmission within 30 days of lumbar spine surgery.[20] Fry et al. reported that seizures, sepsis, wound complications, pneumonia, and postoperative infections were the most common causes for readmission after elective cranial surgery for mass lesion.[18] Lau et al. reported that wound infection, tumor recurrence requiring decompression, postoperative pain control, and proximal junctional kyphosis requiring revision procedure were the most common causes for readmission after spinal chordoma and chondrosarcoma surgery.[19] These reports demonstrated a significant overlap between the causes for readmission for cranial and spinal surgery. Therefore, the use of certain preventative measures by hospitals to minimize occurrence of these complications might help to reduce the total cost of care. [21, 22] For the 4th - 12th- month post-discharge, groups 2 and 3 had higher readmissions rate and median payments in comparison to group 1.

Over time, each individual group showed a downward trend in hospital readmission rate, outpatient service utilization, prescription refills, and median payments. Cranial CC, for the first 6 months post index hospitalization, the readmission rate was 30%, the outpatient services were 113, and the overall median payments were $48,508. For the second 6 months there was a drop-in readmission rate to 14%, outpatient services to 53, and overall median payments to $23,786. Mobile spine CC, during the first 6 months post index hospitalization, the readmission rate was 45%, the outpatient services were 105, and the overall median payments were $49,425. During the second 6 months there was a drop-in readmission rate to 10%, outpatient services to 60, and overall median payments to $22,869. Sacral CC, during the first 6 months post index hospitalization, the readmission rate was 55%, the outpatient services were 119, and the overall median payments were $60,853. During the second 6 months there was a drop-in readmission rate to 9%, outpatient services to 92, and overall median payments to $40,622. These trends are assumed to be due to healing, reduction in postoperative pain and improved functional status with rehabilitation, which lead to less utilization of healthcare services and cost reduction. Off note, hospital readmission was the main factor for the costs incurred during the first 12 months post-discharge and to a lesser extent outpatient services utilization.

There was a significant variability in payments based on insurance type, Medicaid was associated with increased odds for smaller payment for all groups, and Medicare was associated with increased odds for smaller payment only for cranial CC when compared to commercial insurers. Higher EI value (multiple comorbidities) was associated with increased odds for larger payments for all groups, which re-emphasize that managing patients with comorbidities increases the cost of care. To that point, using a tool like the CMS – Human Health Services (HHS) Hierarchical Condition Category (HCC) risk adjustment model can be helpful. This model uses patients' demographic data and coded diagnoses to produce a

risk score that will help with financial estimation.[23] Turcot et al. recently published a report where they tested this model on patients that underwent different spinal surgical interventions. They found that there was a significant association between the HCC score and readmission rates, length of stay, need for reoperation, and cost. [24]

Notably, the current bundles, as indicated on the CMS website include fairly specific clinical situations such as acute Myocardial Infarction, Sepsis, CABG, etc., which are frequent, and well-defined clinical entities. This is important as the calculation of the bundle must be very accurate and based on solid data from a prior experience. Nowhere in the current list of bundles, are any skull base tumors or malignancies, probably because of the difficulty in accurately defining them as individual clinical entities. The choice of chordomas and chondrosarcomas in this study may represent a limitation, given both the rarity of those tumors and the different outcome of those diagnoses. But it can be considered a strength, since the BPCI will eventually be the standard method for payment for all diseases, and there are no reports in the literature that investigated skull base or spinal conditions like chordomas and chondrosarcomas.

The higher cost needed to manage craniospinal chordoma and chondrosarcoma is not limited to a single episode of care, but rather maintained over a period of time. Most of the expenses were during the first 6 months post index hospitalization. The success of BPCI requires a joint effort between insurers and hospitals/providers. Complex neurosurgical conditions like craniospinal CC which has an inherent increased risk for complications, readmissions, and the need for outpatient services. Based on the results of our analyses and to increase the viability and acceptability of BPCI model 2, we suggest the following; BPCI should consider bundling the payments for the index hospitalization and the anticipated services during first 6 months after initial discharge together. Also, it should consider the patients' comorbidities, and for diseases with no curative therapy, the BP model should consider the variability in treatment regimens like the use of experimental and off label treatments. In addition, streamlining payments through minimizing variability in reimbursements between Medicare/ Medicaid and commercial insurers is important. It's well documented that treatment at a center with high case volume is associated with better outcomes and lower complications rate which in turn lead to lower cost. [25-27] Therefore, it may be of importance for the BPCI to stipulate that treatment of certain rare and complex neurosurgical conditions ought to be done at centers of excellence. Hospitals and providers should consider measures to further improve outcomes and decrease cost. Adoption of programs like Enhanced Recovery After Surgery (ERAS) or Enhanced Perioperative Care (EPOC) which aimed at decreasing length of stay, complications rate and readmissions can be valuable to achieve that. [21, 22]

Limitations

The limitations of our study and the MarketScan database should be recognized in the light of the results. The database combined data for both chordoma and chondrosarcoma because both conditions

are coded using the same ICD-10 codes. The database does not include data pertaining to various surgical techniques, the extent of resection, and exact anatomical location of the tumor. In addition, MarketScan database has information on complications, readmission, and outpatient services, but does not include information regarding the details of each, such as causes for readmission, nature of complications, whether radiotherapy was used or not, and type of radiotherapy used. In addition, there is no data on recurrence and need for re-resection. Patients payed out of pocket for treatment were not represented in this report. Finally, local treatment biases might have influenced the data retrieved from the MarketScan database. Therefore, it may not be entirely representative of the national chordoma and chondrosarcoma population. Notably, our data will probably include some cases of osteosarcoma and Ewing's sarcoma due to coding limitations. Nevertheless and because of the size of patient population, our data will have value despite these limitations. Also, primary osteosarcomas of the skull and skull base are quite rare, comprising <2% of all skull tumors. In addition, primary osteosarcoma of the spine is rare as well, accounting for 3%–5% of all osteosarcomas.[28, 29] Ewing's sarcoma occurs mostly in children and we excluded patients with age <18 years. Also, Ewing's sarcoma of the spine is rare, represents approximately 0.9% of all cases.[30, 31]

Conclusion

The fee-for-service system reimbursement is based on the volume of services performed. According to the Centers for Medicare and Medicaid Services (CMS) it is contributing to the rise in healthcare expenditures. The BPCI model aims to improve outcomes and decrease cost. Chordoma and Chondrosarcoma are malignant bony tumors that requires complex surgical intervention, possible radiotherapy, and a battery of outpatient services. Therefore, they are valuable to evaluate the feasibility of BPCI. To succeed, the BPCI should consider patients' comorbidities, disease complexity, and risk for complications. Also, hospitals should take measures to reduce cost through applying quality improvement programs and restrict unnecessary services. We do believe that the BPCI model can be feasible in the case of craniospinal chordoma and chondrosarcoma if stratified by location and if covered the index hospitalization and the 6 months after. Because there were significant differences among the 3 groups in regard to services rendered, complications, and payments. Also, for the whole 12 months follow up period, the first 6 months incurred about 2/3 of the payments.

List Of Abbreviations

CMS; Centers for Medicare and Medicaid Services, BPCI; Bundled Payment for Care Improvement, FFS; fee-for-service, BP; Bundled payment, CHF; Congestive heart failure, COPD; Chronic obstructive pulmonary disease, MI; Myocardial infarction, ICD-9; International Classification of Disease, 9th Revision, HHS; Human Health Services, HCC; Hierarchical Condition Category, ERAS; Enhanced Recovery After Surgery, EPOC; Enhanced Perioperative Care, CC; Chordoma / chondrosarcoma, CABG; Coronary artery bypass graft.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

None

Authors' contributions

ZA analyzed the data and prepared the manuscript, BU & DW retrieved and analyzed the data, NA critically reviewed the manuscript, MB critically reviewed the manuscript, BW critically reviewed the manuscript.

Acknowledgements

None

References

1. Dieleman JL, Baral R, Birger M, Bui AL, Bulchis A, Chapin A, Hamavid H, Horst C, Johnson EK, Joseph J *et al*: **US Spending on Personal Health Care and Public Health, 1996-2013**. *JAMA* 2016, **316**(24):2627-2646.
2. WHO: **Health System Financing**. *Geneva: WHO;* 2010:p. 72-75.
3. Goodwin JS, Singh A, Reddy N, Riall TS, Kuo YF: **Overuse of screening colonoscopy in the Medicare population**. *Arch Intern Med* 2011, **171**(15):1335-1343.
4. Adida E MH, Nassiri S: **Bundled payment vs. fee-for-service: Impact of payment scheme on performance.** *Management Sci* 2017, **63**(5):1606-1624.

5. McLoughlin GS, Sciubba DM, Wolinsky JP: **Chondroma/Chondrosarcoma of the spine**. *Neurosurg Clin N Am* 2008, **19**(1):57-63.
6. McMaster ML, Goldstein AM, Bromley CM, Ishibe N, Parry DM: **Chordoma: incidence and survival patterns in the United States, 1973-1995**. *Cancer Causes Control* 2001, **12**(1):1-11.
7. Hansen LG CS: **Health Research Data for the Real World: The Thomson Reuters MarketScan Databases**. *Truven Health Analytics* 2012.
8. Elixhauser A, Steiner C, Harris DR, Coffey RM: **Comorbidity measures for use with administrative data**. *Med Care* 1998, **36**(1):8-27.
9. Quan H, Sundararajan V, Halfon P, Fong A, Burnand B, Luthi JC, Saunders LD, Beck CA, Feasby TE, Ghali WA: **Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data**. *Med Care* 2005, **43**(11):1130-1139.
10. Parikh AA, Robinson J, Zaydfudim VM, Penson D, Whiteside MA: **The effect of health insurance status on the treatment and outcomes of patients with colorectal cancer**. *J Surg Oncol* 2014, **110**(3):227-232.
11. Walcott BP, Nahed BV, Mohyeldin A, Coumans JV, Kahle KT, Ferreira MJ: **Chordoma: current concepts, management, and future directions**. *Lancet Oncol* 2012, **13**(2):e69-76.
12. Bergh P, Gunterberg B, Meis-Kindblom JM, Kindblom LG: **Prognostic factors and outcome of pelvic, sacral, and spinal chondrosarcomas: a center-based study of 69 cases**. *Cancer* 2001, **91**(7):1201-1212.
13. Omran K, Abdel-Fattah AS: **Posterior Extensive Circumferential Decompressive Reconstructive Technique in Surgical Treatment of Upper Thoracic Spine Compressive Lesions**. *World Neurosurg* 2019, **123**:e501-e508.
14. Di Maio S, Temkin N, Ramanathan D, Sekhar LN: **Current comprehensive management of cranial base chordomas: 10-year meta-analysis of observational studies**. *J Neurosurg* 2011, **115**(6):1094-1105.
15. Ito E, Saito K, Okada T, Nagatani T, Nagasaka T: **Long-term control of clival chordoma with initial aggressive surgical resection and gamma knife radiosurgery for recurrence**. *Acta Neurochir (Wien)* 2010, **152**(1):57-67; discussion 67.
16. Potluri S, Jefferies SJ, Jena R, Harris F, Burton KE, Prevost AT, Burnet NG: **Residual postoperative tumour volume predicts outcome after high-dose radiotherapy for chordoma and chondrosarcoma of the skull base and spine**. *Clin Oncol (R Coll Radiol)* 2011, **23**(3):199-208.
17. Reese JC, Twitchell S, Wilde H, Azab MA, Guan J, Karsy M, Couldwell WT: **Analysis of Treatment Cost Variation Among Multiple Neurosurgical Procedures Using the Value-Driven Outcomes Database**. *World Neurosurg* 2019.
18. Fry DE, Nedza SM, Pine M, Reband AM, Huang CJ, Pine G: **Inpatient and Postdischarge Outcomes Following Elective Craniotomy for Mass Lesions**. *Neurosurgery* 2019, **85**(1):E109-E115.
19. Lau D, Chan AK, Theologis AA, Chou D, Mummaneni PV, Burch S, Berven S, Deviren V, Ames C: **Costs and readmission rates for the resection of primary and metastatic spinal tumors: a comparative**

analysis of 181 patients. *J Neurosurg Spine* 2016, **25**(3):366-378.

20. Jain N, Brock JL, Phillips FM, Weaver T, Khan SN: **30-Day Emergency Department Visits After Primary Lumbar Fusion: Incidence, Causes, Risk Factors, and Costs**. *Clin Spine Surg* 2019, **32**(3):113-119.
21. Dagal A, Bellabarba C, Bransford R, Zhang F, Chesnut RM, O'Keefe GE, Wright DR, Dellit TH, Painter I, Souter MJ: **Enhanced Perioperative Care for Major Spine Surgery**. *Spine (Phila Pa 1976)* 2019, **44**(13):959-966.
22. Smith J, Probst S, Calandra C, Davis R, Sugimoto K, Nie L, Gan TJ, Bennett-Guerrero E: **Enhanced recovery after surgery (ERAS) program for lumbar spine fusion**. *Perioper Med (Lond)* 2019, **8**:4.
23. Killer-Oberpfalzer M, Kocer N, Griessenauer CJ, Janssen H, Engelhorn T, Holtmannspotter M, Buhk JH, Finkenzeller T, Fesl G, Trenkler J *et al*: **European Multicenter Study for the Evaluation of a Dual-Layer Flow-Diverting Stent for Treatment of Wide-Neck Intracranial Aneurysms: The European Flow-Redirection Intraluminal Device Study**. *AJNR Am J Neuroradiol* 2018, **39**(5):841-847.
24. Turcotte J, Sanford Z, Broda A, Patton C: **Centers for Medicare & Medicaid Services Hierarchical Condition Category score as a predictor of readmission and reoperation following elective inpatient spine surgery**. *J Neurosurg Spine* 2019:1-7.
25. Ambekar S, Sharma M, Madhugiri VS, Nanda A: **Trends in intracranial meningioma surgery and outcome: a Nationwide Inpatient Sample database analysis from 2001 to 2010**. *J Neurooncol* 2013, **114**(3):299-307.
26. Barker FG, 2nd, Amin-Hanjani S, Butler WE, Ogilvy CS, Carter BS: **In-hospital mortality and morbidity after surgical treatment of unruptured intracranial aneurysms in the United States, 1996-2000: the effect of hospital and surgeon volume**. *Neurosurgery* 2003, **52**(5):995-1007; discussion 1007-1009.
27. Cowan JA, Jr., Dimick JB, Leveque JC, Thompson BG, Upchurch GR, Jr., Hoff JT: **The impact of provider volume on mortality after intracranial tumor resection**. *Neurosurgery* 2003, **52**(1):48-53; discussion 53-44.
28. Katonis P, Datsis G, Karantanas A, Kampouroglou A, Lianoudakis S, Licoudis S, Papoutsopoulou E, Alpantaki K: **Spinal osteosarcoma**. *Clin Med Insights Oncol* 2013, **7**:199-208.
29. Wu G, Liang Q, Liu Y: **Primary osteosarcoma of frontal bone: A case report and review of literature**. *Medicine (Baltimore)* 2017, **96**(51):e9392.
30. Bellan DG, Filho RJ, Garcia JG, de Toledo Petrilli M, Maia Viola DC, Schoedl MF, Petrilli AS: **Ewing's Sarcoma: Epidemiology and Prognosis for Patients Treated at the Pediatric Oncology Institute, Iop-Graacc-Unifesp**. *Rev Bras Ortop* 2012, **47**(4):446-450.
31. Gopalakrishnan CV, Shrivastava A, Easwer HV, Nair S: **Primary Ewing's sarcoma of the spine presenting as acute paraplegia**. *J Pediatr Neurosci* 2012, **7**(1):64-66.

Tables

Table 1: Demographics stratified by group

	Chordoma / chondrosarcoma				
Variable	**Group 1** Skull and face	**Group 2** Vertebral column	**Group 3** Sacrum/ coccyx	p-value	Combined cohort
Total N= 2041	n= 1214 (69.1%)	n= 297 (16.9%)	n= 246 (14%)		N= 1757
Demographics					
Age				**<.0001**	
Mean (SD)	57.4 (15.8)	49.5 (17)	47.9 (17.2)		54.8 (16.7)
Median (IQR)	58 (49, 69)	52 (37, 62)	49 (35, 61)		56 (45, 65)
Range, min-max)	18-96	18-88	18-89		18-96
Gender: female, n (%)	519 (42.7%)	144 (48.4%)	109 (44.3%)	0.2018	772 (43.9%)
Insurance				**<.0001**	
Commercial, n (%)	726 (59.8%)	203 (68.3%)	181 (73.5%)		1110 (63.1%)
Medicaid, n (%)	144 (11.8%)	42 (14.1%)	30 (12.2%)		216 (12.2%)
Medicare, n (%)	344 (28.3%)	52 (17.5%)	35 (14.2%)		431 (24.5%)
Elixhauser index				0.054	
1, n (%)	415 (34.1%)	85 (28.6%)	72 (29.2%)	0.054	572 (32.5%)
2, n (%)	468 (38.5%)	123 (41.4%)	87 (35.3%)		678 (38.5%)
3+, n (%)	1214 (17%)	297 (15.3%)	246 (14.1%)		1757 (28%)

Table 3: Outcome comparison among groups (12 months follow up)

Variable	Chordoma / chondrosarcoma			p-value	Combined cohort
	Group 1 Skull and face	**Group 2** Vertebral column	**Group 3** Sacrum/ coccyx		
Total N= 2041	n= 1214 (69.1%)	n= 297 (16.9%)	n= 246 (14%)		N= 1757
Index hospitalization outcomes					
Length of stay, median (IQR)	4 (2, 8)	6 (3, 10)	7 (3, 13)	**<.0001**	5 (2, 9)
Prolonged LOS (> Q3+1.5*IQR), n (%)	54 (4.4%)	23 (7.7%)	10 (4%)	0.0501	87 (4.9%)
Payment, median (IQR)	35,490 (19358, 70885)	40,476 (17262, 111365)	44,038 (21954, 93871)	**0.0024**	37,575 (19307, 81444)
Discharge home, n (%)	1087 (89.5%)	222 (74.7%)	179 (72.7%)	**<.0001**	1488 (84.6%)
Complications, n (%)	368 (30.3%)	105 (35.3%)	107 (43.5%)	**0.0002**	580 (33%)
Post discharge outcomes, 30 days					
ER admission, n (%)	118 (9.7%)	35 (11.7%)	44 (17.8%)	**0.001**	197 (11.2%)
Hospital re-admission, n (%)	126 (10.3%)	69 (23.2%)	75 (30.4%)	**<.0001**	270 (15.3%)
Complications, n (%)	214 (17.6%)	72 (24.2%)	73 (29.6%)	**<.0001**	359 (20.4%)
Post discharge outcomes, 3 months					
Hospital admissions					
Admitted, n (%)	251 (20.6%)	114 (38.3%)	110 (44.7%)	**<.0001**	475 (27%)
# readmissions, median	0 (0, 0)	0 (0, 1)	0 (0, 2)	**<.0001**	0 (0, 1)

(IQR)					
Payments, median (IQR), for Admitted	24,116 (11216, 56575)	40,277 (17418, 90354)	42,242 (24991, 122030)	**<.0001**	33,756 (14227, 75308)
Outpatient services					
# services, median (IQR)	67 (24, 126)	58 (29, 106)	64 (29, 122)	0.4646	65 (26, 122)
Payments, median (IQR)	20,522 (4201, 55275)	14,050 (4283, 36340)	13,280 (4199, 33430)	**0.0026**	17,476 (4203, 48565)
Medication refills					
# refills, median (IQR)	8 (2, 16)	8 (2, 17)	10 (1, 17)	0.64	8 (2, 16)
Payments, median (IQR)	405 (24, 1149)	389 (0, 1977)	676 (11, 2243)	**0.0072**	417 (19, 1355)
Overall payments, median (IQR)	27,590 (6011, 68534)	25,968 (7250, 76901)	35,819 (8071, 87857)	**0.0446**	28,292 (6591, 71439)
Post discharge outcomes, 6 months					
Hospital admissions					
Admitted, n (%)	368 (30.3%)	134 (45.1%)	137 (55.6%)	**<.0001**	639 (36.3%)
# readmissions, median (IQR)	0 (0, 1)	0 (0, 1)	1 (0, 2)	**<.0001**	0 (0, 1)
Payments, median (IQR), for Admitted	26,702 (10917, 64297)	46,796 (17418, 119961)	51,364 (24491, 145701)	**<.0001**	363,19 (13396, 84076)
Outpatient services					
# services, median (IQR)	113 (50, 189)	105 (53, 190)	119 (59, 202)	0.1221	112 (52, 192)

Payments, median (IQR)	35,221 (10151, 79143)	25,831 (9187, 69684)	26,880 (8842, 65760)	0.0661	31,478 (9713, 76301)
Medication refills					
# refills, median (IQR)	15 (5, 27)	13 (2, 30)	19 (4, 34)	0.1484	15 (4, 28)
Payments, median (IQR)	804 (75, 2198)	759 (13, 3411)	1458 (86, 4692)	**0.0024**	869 (60, 2587)
Overall payments, median (IQR)	48,508 (15360, 99994)	49,425 (13997, 129738)	60,853 (17459, 158391)	**0.0063**	51,088 (15378, 109462)
Post discharge outcomes, 12 months					
Hospital admissions					
Admitted, n (%)	538 (44.3%)	157 (52.8%)	159 (64.6%)	**<.0001**	854 (48.6%)
# readmissions, median (IQR)	0 (0, 1)	1 (0, 2)	1 (0, 4)	**<.0001**	0 (0, 1)
Payments, median (IQR), for Admitted	30,079 (11720, 70475)	53,276 (16831, 128733)	71,960 (27585, 211350)	**<.0001**	41,437 (14960, 104371)
Outpatient services					
# services, median (IQR)	166 (90, 276)	165 (92, 285)	211 (111, 328)	**0.0002**	173 (93, 287)
Payments, median (IQR)	51,375 (18632, 105100)	40,646 (16729, 113428)	48,804 (20146, 100134)	0.5921	49,700 (17715, 105100)
Medication refills					
# refills, median (IQR)	26 (8, 49)	22 (5, 51)	33 (10, 59)	**0.0389**	26 (8, 51)
Payments, median (IQR)	1477 (189,	1470 (70,	2499 (203,	**0.0005**	1573 (161,

	4113)	7827)	8708)		5102)
Overall payments, median (IQR)	72,294 (28832, 146914)	76,827 (28237, 193631)	101,475 (39062, 244231)	**<.0001**	77,225 (29520, 163677)

Figures

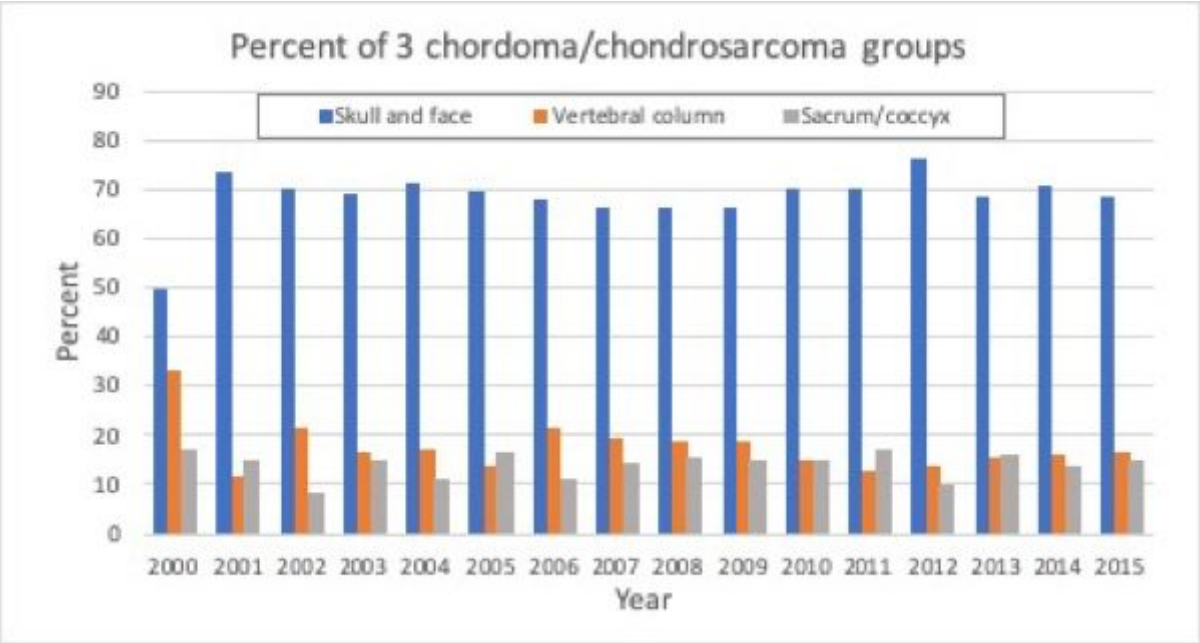

Figure 1

A bar graph shows the percentage of individual group of chordoma and chondrosarcoma (cranial, mobile spine, and sacrococcygeal) over time (2000-2016).

Table 4: Bundled payment, 3 months period

	All patients (N= 2041)			
	Group 1 Skull and face	**Group 2** Vertebral column	**Group 3** Sacrum/ coccyx	
Variables	n= 1214 (69.1%)	n= 297 (16.9%)	n= 246 (14%)	p-value
90-day bundle				**<.0001**
Mean (SD)	105,765 (101523)	140,898 (138743)	145,961 (143723)	
Median (Q1, Q3)	77,598 (39513, 139580)	99,323 (49428, 180441)	103,309 (48361, 192421)	
Min-Max	0-1130642	0-898360	206-1000831	
Index hospitalization				
Total payment				**0.0024**
Mean (SD)	58,130 (69865)	84,854 (109058)	82,440 (109702)	
Median (Q1, Q3)	35,490 (19358, 70885)	40,476 (17262, 111365)	44,038 (21954, 93871)	
Min-Max	0-732975	0-772519	1-940505	
Physician payment				0.0733
Mean (SD)	6051 (9728)	8113 (16816)	6076 (13187)	
Median (Q1, Q3)	3255 (366, 7275)	2750 (420, 8418)	1887 (448, 5614)	
Min-Max	0-118600	0-162038	0-119125	
Hospital payment				**0.0018**
Mean (SD)	35,753 (52372)	50,524 (76451)	49,396 (71568)	
Median (Q1, Q3)	19,602 (10146, 40830)	21,008 (8204, 62631)	25,444 (11934, 60559)	
Min-Max	0-603034	0-572341	0-720467	
90-day post-discharge				
Total payment				**0.0484**
Mean (SD)	47,636 (65458)	56,044 (77843)	63,521 (76930)	
Median (Q1, Q3)	27,404 (5914, 68092)	24,923 (7048, 76730)	35,292 (7983, 87857)	

Min-Max	0-1090012	0-525663	0-360038	
Re-admission payment				**<.0001**
Mean (SD)	9900 (42208)	26,549 (60722)	35,003 (62071)	
Median (Q1, Q3)	0 (0, 0)	0 (0, 22266)	0 (0, 37832)	
Min-Max	0-1074424	0-484967	0-279163	
Outpatient services payment				**0.002**
Mean (SD)	36,637 (49919)	27,202 (39092)	25,958 (36611)	
Median (Q1, Q3)	20,027 (4129, 54781)	13,777 (4092, 33597)	12,775 (4146, 32938)	
Min-Max	0-793307	0-274015	0-254750	
Medication payment				**0.0121**
Mean (SD)	1099 (2842)	2293 (5404)	2560 (5012)	
Median (Q1, Q3)	394 (23, 1123)	389 (0, 1977)	631 (9, 2222)	
Min-Max	0-61580	0-35502	0-30726	

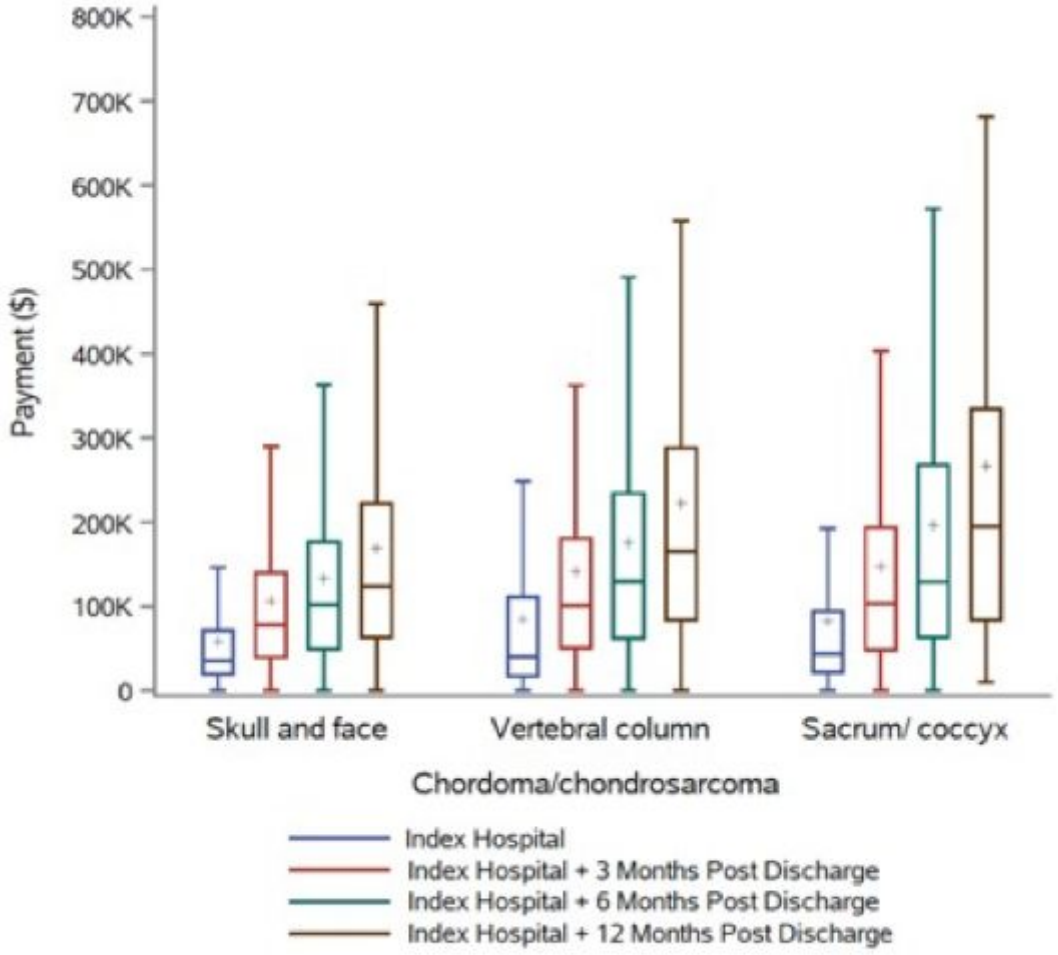

Figure 2

A box and whisker graph show the cumulative payments for managing chordoma/ chondrosarcoma over 12 months divided by groups.

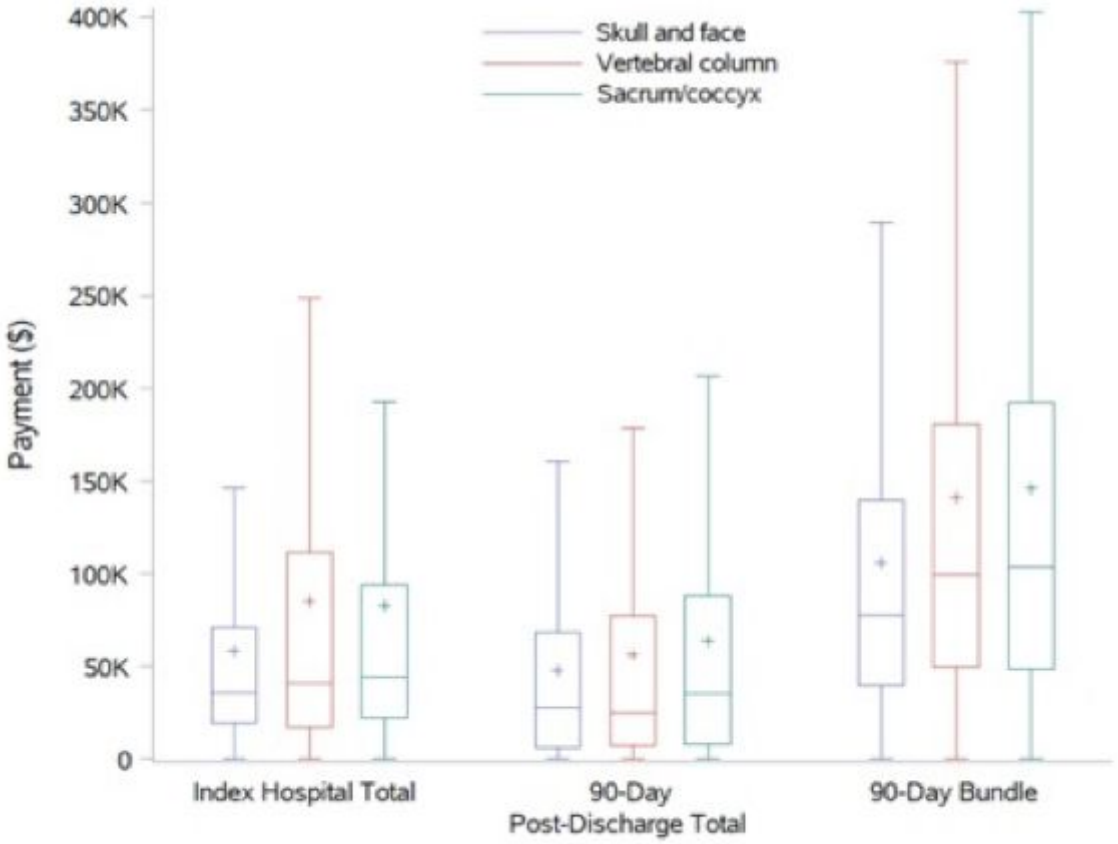

Figure 3

A box and whisker graph show the payments for index hospitalization, 90 days post discharge, and combined “bundled” payments for managing chordoma/ chondrosarcoma divided by groups.