Extracranial-intracranial bypass surgery: impact of caseload

Impact of Hospital Caseload and Elective admission on Outcomes Following Extracranial-Intracranial Bypass Surgery

Abstract

Background

Limited information exists evaluating the impact of hospital caseload and elective admission on outcomes following patients undergoing extracranial-intracranial (ECIC) bypass surgery. Using the Nationwide Inpatient Sample (NIS) for the years 2001 through 2014, we evaluated the impact of hospital caseload and elective admission on outcomes following bypass.

Methods

In an observational cohort study, weighted estimates were used to investigate the association of hospital caseload and elective admission on short-term outcomes following bypass surgery using multivariable regression techniques.

Results

Overall 10, 679 patients (mean age: 43. 39±19. 63 years; 59% female) underwent bypass across 495 non-federal US hospitals. In multivariable models, we noted patients undergoing bypass at high volume centers were associated with decreased probability of mortality(OR: 0. 39; 95% CI: 0. 22-0. 70; p <0. 001), LOS(OR: 0. 86; 95% CI: 0. 82-0. 90; p <0. 001), post bypass neurologic complications(OR: 0. 66; 95% CI: 0. 49-0. 89; p= 0. 007), VTE events (OR: 0. 69; 95% CI: 0. 49-0. 97; p= 0. 033), and ARF(OR: 0. 45; 95%

CI: 0. 26-0. 80; p= 0. 007), and higher hospitalization cost (26. 3% higher) compared to low volume centers. Likewise, patients undergoing elective bypass were associated with decreased likelihood of mortality(OR: 0. 38; 95% CI: 0. 25-0. 59; p <0. 001), unfavorable discharge (OR: 0. 57; 95% CI: 0. 43-0. 76; p <0. 001), LOS(OR: 0. 62; 95% CI: 0. 59-0. 64; p <0. 001), VTE (OR: 0. 61; 95% CI: 0. 49-0. 77; p <0. 001), ARF (OR: 0. 64; 95% CI: 0. 43-0. 94; p= 0. 022), and wound complications (OR: 0. 71; 95% CI: 0. 53-0. 96; p= 0. 028), and lower hospitalization cost (34. 5% lower) compared to non-elective admissions.

Conclusions

Our findings serve as a framework for strengthening referral networks for complex cases to centers performing high volumes of cerebral bypass. Also, our study supports improved outcomes in select patients undergoing elective bypass procedure.

Introduction

Extracranial-intracranial (ECIC) bypass is a complex cerebral revascularization technique indicated in patients with symptomatic moyamoya disease [1-3] and complex intracranial aneurysms not amenable to traditional clipping or endovascular treatment modalities. [4-6] Despite initial setbacks following publication of the maiden randomized trial, [7] ECIC bypass is a valuable tool in the armamentariumof cerebrovascular surgeons. Other indications for bypass include cerebro-occlusive disease (COD) refractory to medical treatment [8, 9] , resection of certain low-grade malignancies at the base of the skull that involve ICA, [9, 10] and in intraoperative emergencies. [11]

Owing to the complexity of the procedure, outcomes following EC-IC bypass is dependent on a multitude of factors including but not limited to surgeon expertise, hospital caseload, patient selection and comorbidities, and maintaining post-procedural bypass patency. Although previous studies demonstrated high-volume hospitals to be associated with favorable short-term outcomes in patients undergoing neurosurgical interventions, [12-19] hospital caseload as a proxy for outcomes in cerebrovascular surgery is often debated. [20-23] As a subset analysis on hospital caseload, Amin-Hanjani et al demonstrated patients receiving EC-IC bypass at high-volume centers (1992-2001) were associated with improved discharge disposition. [24] Limited literature exists evaluating the impact of ECIC bypass hospital caseload exclusively on outcomes such as length of stay (LOS), costs, and post-surgical complications in a comprehensive manner. Recent reports document favorable functional outcomes following bypass surgeries at low volume centers. [25-27] Improvisation in technique, advent of neuroimaging modalities, as well as efforts to better define the patient subgroups that could benefit from this surgery could be responsible for improvement of outcomes in these low volume centers. However, the findings are subjected to selection bias considering its retrospective design from single institution. Further, the impact of elective admission for bypass is relatively unknown. Elective bypass procedure is pertinent in the settings of moyamoya disease or asymptomatic CODs. To this effect, we used an all-payer cohort, the

Nationwide Inpatient Sample (NIS) that incorporates data from diverse clinical locations. Using the NIS, we investigated the impact of hospital caseload and elective admissions on outcomes following ECIC bypass surgery.

Methods

Data Source and cohort definition

The NIS database, developed by the Agency for Healthcare Research and Quality (AHRQ, Rockville, Maryland) for the Healthcare Research and Quality (HCUP), for the years 2001 through 2014 was utilized for the current observational cohort study. The NIS is the largest inpatient, publicly available all-payer cohort. When unweighted, it contains 5 to 8 million discharge-level records each year from over 1000 participating non-federal hospitals from several states. [28] The database contains discharge-level weights for national estimates. The clinical data in the NIS is coded using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes into several diagnoses and procedures [29] . An overview of the database can be accessed athttp://www. hcup-us. ahrq. gov/nisoverview. jsp. For the years studied, we extracted patients that underwent EC-IC bypass surgery using the ICD-9-CM procedure code 39. 28 by merging relevant data source files [Figure 1]. Common indications for bypass surgery were identified using appropriate coding definitions [Online Supplement: Table I].

Outcome Measure (endpoint)

The primary outcome measure was inpatient mortality, discharge disposition, LOS, hospitalization cost, and post-bypass complications such as neurological, cardiac, wound complications, infections, venous thromboembolic (VTE) events, and acute renal failure (ARF). Discharge disposition was dichotomized as routine and unfavorable. Any discharge other than to home or home healthcare services was labelled as unfavorable. For hospitalization cost, we applied the HCUP group average cost-to-charge ratios to hospital charges, modelled on hospital accounting reports from the Centers for Medicare and Medicaid Services. [30] Charges reflect the amount billed by the hospital for inpatient hospitalization, albeit excluding physician fees, while cost provides estimate on the actual incurred expenses in the production of hospital services including wages, supplies, and utilities. Considering the data spread over several years, inflation adjustment of the cost data to represent 2016 dollar value was performed. [31]

Explanatory Variables

Primary explanatory variables of interest were hospital case load and admission type. For computing hospital caseload, we used the hospital identifier number for individual case records. For all analysis, weighted estimates using the recently introduced HCUP weighted discharge (TRENDWT) were preferentially used over the original weights (DISCWT) to account for the change in sampling design of the NIS databases for the years utilized. [32] Total number of bypass surgeries across centers (N= 495) over the 14-year study period was noted. Based on the number of bypass procedures performed per hospital, centers were labelled as a low-volume center (LVC) if it performed 14 or less (1/year on average), or a medium volume center (MVC) if 15 to 280 procedures (2-20/year), or a high-volume center (HVC) if more than 280 bypass (> 10/year) over the 14-year study period. Subsequently, each case was labelled as having undergone a bypass at a LVC (n= 343), or an MVC (n= 148) or a HVC (n= 4). These caseload assignments and cutoff values were selected preferentially selected based upon the skewed distribution of volumes across centers performing bypass.

Covariates used for risk adjustment included patient demographics [age, gender, race, primary payer, quartiles of median household income per patients' residential zip code], and hospital data [bed size, academic status, region]. For modelling patient comorbidities in case-mix adjustment, we used the Charlson et al comorbidity index [33] as modified by Deyo et al [34] to be applied on ICD-9 coding definitions. [35]

Statistical Analysis

Categorical data is reported as frequencies and proportions, while metric values are presented as mean ± SD and/or median (IQR) as appropriate. Differences in proportions across patients admitted at centers with variable caseloads and based upon admission status were analyzed using the Pearson $\chi 2$ test. For comparison of metric values across hospital caseloads, one-way ANOVA or Kruskal Wallis was used while independent samples t-test or Wilcoxon-Rank -Sum test across admission type, as appropriate.

To examine the association of primary explanatory variables with outcomes, multivariable analytical models were constructed while controlling for all covariates described above. Considering the nature of the database, we fitted all log-binomial models with generalized estimating equations (GEE) using the sandwich variance covariance matrix estimator as described by Huber and White to account for clustering of outcomes within hospitals. [36-39] Metric endpoints (cost and LOS) were modelled using an ordinary least square (OLS) regression. Initial analysis of hospital cost demonstrated remarkable degree of non-Gaussian distribution, and construction of OLS models resulted in heteroskedastic variance in errors. To mitigate this, transformation of cost data was attempted using several methods. Natural logarithmic (ln) transformation provided the best fit to normality, following which an OLS model was constructed for hospital cost with all previously described covariates. For non-binary categorical variables, dummy variables were introduced. Residual patterns were assessed along with other regression diagnostics. For interpretation of effect of hospital caseload and elective admission on hospital cost, we back transformed the estimates as a function of percentage change to the cost value. Similar to cost analysis, we assessed LOS for distribution prior to constructing multivariable models, and noted positive skewness and overtly dispersion of LOS. Therefore, a log-link model with a negative binomial distribution accounting for within hospital correlation of outcomes was selected over Poisson count model or log transformation with OLS for modelling LOS.

Prior to constructing multivariable models, we noted missing values for several explanatory variables. To prevent bias from missing variables, we used a model-based multiple imputation technique over traditional deletion methods and single imputation technique. Multiple imputation is valuable tool especially dealing with large datasets, [40-44] and have been used in several previous studies. [13, 14, 45, 46] Following assessment of proportion of missing values for several explanatory variables (Online Supplement: Table II), we evaluated patterns of missing. Subsequently, based upon model variables, imputed datasets were generated (n= 5). In all models, imputed datasets were introduced, and estimates from pooled datasets are reported.

As a part of sensitivity analysis, estimates of hospital caseload and elective admission status was assessed using non-imputed datasets using GEE and *logit* models. Further assessment using 1000 bootstrapped replacement samples was performed. These estimates closely resembled our findings from primary analyses; therefore they are not being reported separately. All statistical analyses were conducted using SPSS version 22. 0 (IBM, Armonk, NY) and Stata14. 0 MP (StataCorp, LP, College Station, TX). All statistical tests were two tailed, and alpha ≤ 0. 05 was considered statistically significant.

Results

Patient Characteristics and Outcomes

Based upon available data in the NIS using weighted estimates, 10, 679 patients were known to have undergone ECIC bypass surgery across 495 non-federal US hospitals between 2001 and 2014. Overall, the mean age of the cohort was 43. 39 ± 19. 63 years, and 59% were female (Table 1). Majority of patients underwent bypass at medium volume centers (n= 6836; 64%) followed by LVC (n= 2160; 20%) and HVC (N= 1683; 16%). Major indications for bypass were moyamoya disease (n= 5381; 50. 4%), followed by COD (asymptomatic: 20. 8%; symptomatic: 9. 6%) and aneurysms (unruptured: 10. 5%; ruptured: 4. 3%). Demographic and clinical characteristics of patients across centers with variable caseload are presented in Table 1. Of the 10, 088 patients with available data regarding admission status, 7183 (71%) were elective admissions. An overview of patient demographics and clinical characteristics based upon admission type is depicted in Table 2.

High volume centers and outcomes

As compared to patients at LVC, those undergoing bypass surgery at HVCs had lower mortality (1. 2% vs 2. 7%), unfavorable discharge (21. 4% vs 23. 1%), acute renal failure (1. 5% vs 2. 8%), postoperative cardiac complication (3. 3% vs 3. 5%), and hospitalization stay (mean, days: 7. 44 vs 8. 54) [Table 3]. Interestingly, patients at HVCs on an average incurred higher cost for hospitalization ($68, 350 vs $41821) [Table 3]. In adjusted multivariable analytic models, controlled for clustering at hospital-level, we noted patients undergoing bypass at HVCs were associated with decreased probability of mortality (OR: 0. 39; 95% CI: 0. 22-0. 70; p <0. 001), LOS (OR: 0. 86; 95% CI: 0. 82-0. 90; p <0. 001), post bypass neurologic complications (OR: 0. 66; 95% CI: 0. 49-0. 89; p= 0. 007), VTE events (OR: 0. 69; 95% CI: 0. 49-0. 97; p= 0. 033), and ARF (OR: 0. 45; 95% CI: 0. 26-0. 80; p= 0. 007) [Figure 2]. No differences between HVCs and LVCs were observed in terms of discharge disposition and wound complications. Patients at HVC were associated to incur higher cost compared to LVC (26. 3% higher) [Figure 2]. On the contrary, patients at HVCs were associated with higher odds for post-bypass cardiac (OR: 1. 69; 95% CI: 1. 09-2. 62; p= 0. 019).

Medium volume centers and outcomes

Patients at MVCs had lower unfavorable discharge (21. 9% vs 23. 1%) and acute renal failure (1. 4% vs 2. 8%) but higher hospitalization stay (mean days: 10. 1 vs 8. 54), hospital cost (mean: $55, 550 vs $41, 821), and post bypass neurological complications (9. 2% vs 6. 2%) [Table 3]. In multivariable analytic models, patients at MVC were less likely associated with development of ARF compared to LVCs (OR: 0. 58; 95% CI: 0. 35-0. 83; p= 0. 025) [Figure 3]. No differences were noted for inpatient mortality, discharge disposition, VTE events, wound complications and cardiac complications between MVCs and LVCs following bypass surgeries [Figure 3]. Interestingly, as observed for HVCs, MVCs were associated with higher hospitalization costs (11. 7% higher). Furthermore, patients at MVCs had higher probability for neurological complications (OR: 1. 29; 95% CI: 1. 03-1. 63; p= 0. 030) and higher hospital stay (OR: 1. 13; 95% CI: 1. 09-1. 18; p <0. 001) [Figure 3].

Elective admission and outcomes

Patients undergoing elective bypass had significantly lower mortality (1. 1% vs 5. 5%; p <0. 001), unfavorable discharge (14. 8% vs 41. 1%; p <0. 001), neurological complications (7. 7% vs 10. 0; p <0. 001), infections (0. 5% vs 1. 6%; p <0. 001), hospital stay (mean days: 6. 35 vs 11. 20), and costs ($ 43, 778 vs $84, 454; p <0. 001) [Table 4]. In multivariable regression models controlled for confounders, patients with elective admissions were associated with decreased likelihood of mortality (OR: 0. 38; 95% CI: 0. 25-0. 59; p <0. 001), unfavorable discharge (OR: 0. 57; 95% CI: 0. 43-0. 76; p <0. 001), LOS (OR: 0. 62; 95% CI: 0. 59-0. 64; p <0. 001), VTE (OR: 0. 61; 95% CI: 0. 49-0. 77; p <0. 001), ARF (OR: 0. 64; 95% CI: 0. 43-0. 94; p= 0. 022), and wound complications (OR: 0. 71; 95% CI: 0. 53-0. 96; p= 0. 028). Elective admissions were also associated with lower hospitalization cost (34. 5% lower) compared to non-elective admissions. Interestingly, elective admissions were noted to have higher neurological complications following bypass surgery (OR: 1. 57; 95% CI: 1. 26-1. 95; p <0. 001) [Figure 4].

Discussion

Our study examines the impact of hospital caseload and elective admission on short-term outcomes following ECIC bypass surgery. Using data obtained from the NIS over a 14-year span (2001-2014), our study provides the latest follow up on bypass procedures in the US. Comprising data from diverse clinical practice settings and inclusive of all-payers, the database enables generalizability of results. For analysis pertaining to our study, we applied appropriate weights as provided by the HCUP to represent national estimates and to compute hospital volumes. Using robust statistical techniques based upon the design of the database, we quantified the association of high-volume centers and elective admissions with mortality, LOS, and post-procedural complications. ECIC bypass is technically challenging, requires specialized skillsets and a multi-disciplinary team for pre-surgical and post-operative care. Due to limited indications for bypass and the risks associated with it, it is performed by a limited number of cerebrovascular surgeons and fewer hospitals. Centers of excellence for bypass procedures plausibly are equipped with modern infrastructure, adequate intensive monitoring facilities; provide streamlined approach and efficient care, and intuitively are associated with superior functional outcomes. Overall, we observed patients undergoing bypass at HVCs and as an elective procedure were noted to have better outcomes. Although, the absolute estimates of bypass hospital caseload and outcome may vary across known indications of bypass.

In a recent analysis, Bekelis and colleagues investigated the impact of provider (treating neurosurgeon) procedural volume for cerebrovascular interventions with inpatient mortality, discharge disposition and LOS in pediatric population. [47] Using advance observational techniques, the author's note that high annual procedural volume (> 20) is associated with lower mortality (OR: 0. 09; 95% CI: 0. 02-0. 54; p <0. 001), lower rate of discharge to rehabilitation facility (OR: 0. 35; 95% CI: 0. 22-0. 55; p <0. 001) and lower LOS (-2. 6; 95% CI:-3. 8 to -1. 3; p <0. 001). However, limited information exists on hospital caseload on outcomes exclusively for cerebral revascularization procedures. In a population based study using data from 1992 to 2001, Amin-Hanjani et al investigated outcomes in patients with COD and intracranial aneurysms undergoing bypass procedure. [24] The authors report high-volume centers fare better in terms of discharge disposition; however noted no significant association of hospital caseload with mortality. Further, the authors observed no significant association of surgeon volume with mortality, discharge disposition of postoperative complications following bypass. [24] Our analysis limited to hospital caseload with outcomes demonstrates a slight variation with that reported by Amin-Hanjani and colleagues. We note hospitals performing an average of over 20

ECIC bypass surgery in comparison to those performing 1 or less are associated with lower mortality (OR: 0. 38; 95% CI: 0. 25-0. 59; p <0. 001). No differences were noted in terms of discharge disposition across HVCs and LVCs. The inconsistencies in these findings could possibly be linked to evolving resuscitation techniques, intraoperative technologies including advancement in imaging techniques such as wide availability of ICG or intraoperative A-gram for evaluating graft patency, and surgeon expertise over the years considering bypass is performed by limited surgeons. The differences could also be attributed to variability in definitions of hospital volumes and investigated indications for bypass. However, we noted no differences in mortality and discharge disposition between MVCs and LVCs in terms of mortality and discharge disposition. On the contrary, single institutional studies from centers with low ECIC bypass volume have demonstrated improved functional outcomes, lesser complications and lower costs. [25-27]

Additionally, we examined the association of elective admission for bypass with short-term outcomes. Prompt cerebral revascularization is critical in patients with moyamoya angiopathy and complex cases of aneurysms. Most patients with moyamoya disease and selective unruptured aneurysms are usually elective candidates for bypass. This was reflected in our analysis as well with higher proportion of patients with moyamoya disease (58. 5% vs 34. 2%; p <0. 001) and asymptomatic COD (21. 5% vs 15. 9%; p <0. 001) undergoing elective bypass compared to non-elective admissions. Predefined planning as in patients with elective admissions is therefore known to have better outcomes. Our analysis reflected elective admissions to be associated with significantly lower likelihood of inpatient mortality, unfavorable discharge, LOS, hospitalization costs, and other post-bypass complications. Emergent bypass indication, mostly warranted intraoperatively, is likely to increase costs and is high-risk for complications. As noted, high proportion of patients with ruptured aneurysms (12. 2% vs 0. 8%; p <0. 001) and COD (21. 1% vs 5. 1%; p <0. 001) with stroke underwent emergent bypass procedure compared to elective admission [Table 2]. These findings support the feasibility of elective bypass in select patients following determination of patient selection incorporating hemodynamic and other parameters. [48-52]

Limitations concerning the use of administrative databases or registries are well known, and apply to the current study as well. As data in the NIS are encoded using ICD-9 coding definitions, coding errors cannot be ruled out. Fidelity of ICD-9 procedure code 39. 28 for bypass in differentiating between indirect and direct technique is debatable. Specific information relating to type of graft utilized (auto versus allograft), procedural time, volume of blood loss, graft patency, hemodynamic and radiological parameters known to impact outcomes are not recorded in the NIS. Further, the NIS lacks information of disease severity such as grading for determining hemorrhage in patients with rupture, degree of occlusion in patients with COD, aneurysmal morphometrics, and functional outcomes. For the years utilized, NIS does not include data across all states. The NIS enables analysis of outcomes limited to inpatient events only. Lack of outpatient and longitudinal data limits long-term assessment of outcomes. The estimates cannot predict causality due to the observational design of our study.

Nonetheless, the database provides sufficient sample to test for preliminary hypothesis for future research design.

Conclusion

Using the NIS, we investigated the impact of hospital caseload and elective admissions on outcomes in patients undergoing ECIC bypass surgery for various indications. Patients at high-volume centers were associated with better short-term outcomes, albeit associated with significantly higher hospitalization cost. Likewise, patients undergoing elective bypass procedure were associated with better outcomes and lesser hospitalization costs. Nonetheless, our findings serve as a framework for strengthening referral networks for complex cases to centers performing high volumes of cerebral bypass.