

Clinical Characteristics, Outcomes, Revision Rates, and Economic Impact of Ventricular Shunt Surgery in Pediatric Patients

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Abstract

Objective

To describe the clinical features, treatment modalities, and frequency of surgical revisions in pediatric patients who underwent ventricular shunt procedures.

Methods

A retrospective, descriptive, observational study was conducted at the *Hospital de Pediatría "Dr. Silvestre Frenk Freund,"* National Medical Center "*Siglo XXI.*" Medical records of 371 patients aged 0–16 years who underwent ventricular cerebrospinal fluid diversion surgeries between January 2013 and May 2021 were analyzed. Demographic data, etiology, surgical modality, and revision frequency were collected and analyzed using descriptive statistics.

Results

Among the 371 patients, 59% were male and 41% were female. The primary etiologies were congenital malformations (37%), neoplasms (24%), hemorrhage (14%), infections (10%), trauma (5%), cysts (5%), and idiopathic causes (4%). Of the cohort, 59.8% required only one surgery, while 40.2% underwent multiple surgical interventions, with a maximum of 22 surgeries in one patient. Initial treatment predominantly involved external ventricular drainage (50.2%), followed by ventriculoperitoneal shunt placement (41.0%). Notably, 38% of patients with initial ventriculoperitoneal shunt placement required at least one revision surgery.

Conclusion

Ventricular shunt surgery remains a critical intervention in pediatric neurosurgery, often requiring multidisciplinary management. Despite advancements, a significant proportion of patients require multiple interventions, highlighting the need for improved surgical techniques and postoperative care strategies. This study provides a foundation for future prospective studies aimed at reducing revision rates and improving outcomes.

INTRODUCTION

Hydrocephalus is an ancient disease whose management has evolved dramatically with advances in neurosurgery and biomedical engineering.^{1,2} Initially a uniformly fatal condition, the development of implantable CSF (cerebrospinal fluid) shunt systems in the 20th century transformed hydrocephalus into a manageable entity, particularly in pediatric populations.^{3–6} Despite technological progress,

hydrocephalus remains complex, with diverse etiologies and a persistent risk of shunt failure requiring revision surgeries.^{7–9}

In addition to the clinical challenges, the management of hydrocephalus imposes a considerable financial burden on healthcare systems and families. Lim, et al¹⁰ estimated that the total average cost of a VP (ventriculoperitoneal) shunt surgery in pediatric patients, including hospitalization and follow-up for 12 months, is approximately \$130,839 USD. Meanwhile Lam et al¹¹ found that the average cost of hospitalization for the initial placement of a VP shunt is \$49,317 USD, with an average hospital stay of 18.2 days.

The costs of VP shunt surgery in Mexico are significantly lower than in the United States, which can represent an economic advantage for patients.¹² However, it is important to consider that costs may vary depending on the complexity of the case, the need for revision surgeries, and the length of hospitalization.

This study aimed to describe the clinical characteristics, treatment modalities, and revision frequencies in a large cohort of pediatric patients undergoing ventricular shunt procedures at a high-volume tertiary care center in Mexico. Additionally, a basic cost analysis of a ventriculoperitoneal shunt surgery was performed

MATERIALS AND METHODS

A retrospective observational study was conducted at the *Hospital de Pediatría "Dr. Silvestre Frenk Freund,"* National Medical Center "Siglo XXI." Inclusion criteria were patients aged 0–16 years diagnosed with hydrocephalus or related pathologies requiring CSF diversion procedures from January 2013 to May 2021. Patients treated initially at other institutions or without complete follow-up were excluded.

Data collected included age, sex, primary diagnosis, surgical modality, and number of surgical revisions. Statistical analysis was performed using SPSS version 21, applying descriptive statistics for categorical and continuous variables.

The economic impact was estimated average cost of \$6,000 USD per surgical procedure — including hospitalization, surgical materials, and postoperative care according to the "*Catalog of Interventions, Treatments, Auxiliary Diagnostic Services and Rates for the Exchange of Services 2022 published*" by the Mexican Government.¹²

The study protocol was approved by the Institutional Review Board and the Ethics committee of Hospital de Pediatría "Dr. Silvestre Frenk Freund," National Medical Center "Siglo XXI." I.M.S.S, under the number project R-2021-3603-061

RESULTS

A descriptive, retrospective, observational, and cross-sectional study was conducted, including a total of 371 pediatric patients who underwent ventricular cerebrospinal fluid (CSF) diversion procedures. Of 371 patients included, 220 (59%) were male and 151 (41%) were female. The age distribution is shown in Table 1

Table 1
Patients distribution according age group

Age Group	n (%)
0–28 days (Neonates)	101 (27.2%)
29 days–24 months (Infants)	79 (21.3%)
24 months and 1 day–6 years	68 (18.3%)
6 years 1 day–12 years	72 (19.4%)
12 years 1 day–16 years	51 (13.8%)
Total	371 (100%)

Primary etiologies were congenital malformations (37%), neoplasms (24%), hemorrhage (14%), infections (10%), trauma (5%), cysts (5%), and idiopathic causes (4%). A total of 729 surgical procedures were recorded among the 371 patients; initial surgical interventions included: external ventricular drainage (50.2%), ventriculoperitoneal shunt placement (41.0%), endoscopic procedures (4.1%), cystoperitoneal shunt placement (1.8%) and other procedures (< 2%). The rest of the results are shown in table Fig. 1

Regarding outcomes, 222 patients (59.8%) required only one surgical intervention. The remaining 149 patients (40.2%) underwent multiple interventions. Among these, the number of surgeries ranged from 2 to 22, with a median of two revisions. Figure 2

Figure 2

Among the 257 patients initially treated with a ventriculoperitoneal shunt: 159 patients (62%) had successful outcomes without the need for revision and 98 patients (38%) required at least one revision surgery.

Economic Impact Estimation

Using an estimated average cost of \$6,000 USD per surgical procedure — including hospitalization, surgical materials, and postoperative care — the total healthcare expenditure for the cohort was approximately: $729 \times 6000 = 4,374,000$ USD. (Table 2 & Fig. 3)

Table 2
Summary of Estimated Surgical Costs

Concept	Value
Total number of patients	371
Estimated average cost per surgery	\$6,000 USD
Estimated total cost (entire cohort)	\$4, 374,000 USD
Estimated average cost per patient	\$11,789 USD

Figure 3

DISCUSSION

This study reflects the persistent challenges associated with the surgical management of hydrocephalus and related conditions in pediatric patients. Although a majority achieved satisfactory outcomes with a single intervention, a substantial proportion required multiple surgeries, consistent with international literature.

In studies from Anglo-Saxon countries, such as the United States and the United Kingdom, the rate of shunt revision ranges between 30% and 50% within the first two years post-implantation.^{13–15} Our observed revision rate (40.2%) is within this range, suggesting that, despite institutional and regional differences, shunt failure remains a universal challenge in pediatric hydrocephalus care.

The distribution of etiologies in our cohort also differed from that reported in high-income countries. While congenital malformations were the leading cause of hydrocephalus in our study (37%), other studies have reported a predominance of post-hemorrhagic hydrocephalus secondary to prematurity, likely reflecting differences in neonatal intensive care outcomes.^{16–20}

The high frequency of initial external ventricular drainage (EVD) procedures observed in our population (50.2%) suggests a pattern of cautious management in unstable or complex cases before definitive shunting. This practice contrasts with centers that favor early definitive shunt placement to minimize infection risk, highlighting variations in institutional protocols.^{21–23}

Several factors may contribute to the revision rates observed, including patient comorbidities, infection rates, valve malfunction, and resource variability.^{22–25} Recent advances such as antibiotic-impregnated catheters and programmable valves have demonstrated potential to reduce revision rates, yet access to such technologies remains limited in many middle-income countries.^{24,25}

The economic impact is also considerable. Our analysis estimated an average cost of approximately \$11,789 USD per patient, rising significantly for patients undergoing multiple revisions. This financial

burden, combined with increased morbidity and prolonged hospitalizations, underscores the need for multidisciplinary strategies aimed at reducing shunt failure rates.

Overall, our findings align with international trends while reflecting regional epidemiological and resource-specific realities. Continuous monitoring of outcomes, adherence to best surgical practices, and access to advanced technologies will be critical to improving long-term prognoses in pediatric hydrocephalus.

Strengths and Limitations

Strengths

One of the main strengths of this study is the relatively large sample size, comprising 371 pediatric patients treated over an eight-year period at a major national referral center. This enhances the generalizability of the findings within similar healthcare contexts.

Additionally, the inclusion of detailed surgical and revision data allows for a comprehensive analysis of treatment modalities, outcomes, and economic implications. The study also highlights local epidemiological characteristics that are underrepresented in international literature, providing valuable insights for future regional healthcare planning.

Limitations

As a retrospective observational study, this analysis is inherently subject to selection and information biases. Data were obtained from clinical records, which may have inconsistencies or missing information not accounted for during the review.

Moreover, the study was conducted at a single center, limiting the ability to generalize findings to other institutions with different patient populations or healthcare resources.

Another limitation is the lack of detailed stratification by hydrocephalus severity, shunt type, and valve characteristics, which could influence revision rates.

Finally, while an economic estimate was provided, it did not capture indirect costs such as outpatient visits, rehabilitation needs, or caregiver burden, potentially underestimating the true societal cost of hydrocephalus management.

Future prospective, multicenter studies are needed to validate these findings and to further explore interventions that could reduce surgical revisions and optimize cost-effectiveness.

CONCLUSION

Hydrocephalus management in pediatric populations continues to present significant challenges, particularly regarding surgical revision rates. This study underscores the importance of comprehensive

perioperative care, vigilant postoperative monitoring, and ongoing research to identify modifiable risk factors for shunt failure. Future prospective studies are warranted to develop strategies that can reduce the burden of surgical revisions and improve patient quality of life

Ventricular cerebrospinal fluid diversion remains a cornerstone of pediatric neurosurgical practice, yet it continues to present significant challenges. In this retrospective analysis, we observed that while a majority of patients achieved favorable outcomes with a single procedure, a substantial proportion (40.2%) required multiple surgical interventions. This finding aligns with international data and underscores the persistent burden of shunt failure in pediatric populations.

The predominance of congenital malformations as the underlying etiology in our cohort highlights regional epidemiological differences compared to other reports, where post-hemorrhagic hydrocephalus is more prevalent. These differences should be considered when designing preventive strategies and early management protocols tailored to specific healthcare settings.

Our findings also reveal that the economic impact of shunt surgeries and revisions is considerable, with an estimated average cost per patient exceeding \$11,000 USD, and significantly higher in those requiring multiple interventions. In this context, efforts to reduce revision rates are not only medically necessary but also economically imperative, particularly in middle-income countries where healthcare resources are limited.

To improve long-term outcomes, a multidisciplinary approach involving neurosurgeons, infectious disease specialists, rehabilitation teams, and caregivers is essential. Furthermore, access to advanced technologies such as antibiotic-impregnated shunt systems, programmable valves, and enhanced perioperative protocols could play a critical role in minimizing complications and optimizing surgical success.

Future prospective studies are warranted to identify modifiable risk factors for shunt failure, evaluate the effectiveness of new technologies, and develop regionally appropriate clinical guidelines. A stronger emphasis on individualized patient care and preventive strategies could ultimately reduce the physical, emotional, and financial burden of hydrocephalus management in pediatric populations.

In conclusion, while significant advances have been made, pediatric hydrocephalus management remains a complex and evolving field. Continuous monitoring, innovation, and investment in healthcare infrastructure are vital to ensuring better outcomes for affected children worldwide.

Declarations

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Competing interests: The authors declare that they have no competing interests.

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Author contribution: UECR, MEPS and JCLV—conceptualization, writing initial draft and database creation. UECR, DAVM and JCLV—data collection, statistics analysis, editing, translation and supervision. DMB, EFHG and ZESR, data collection and second editing. LMO and JCLV: supervision and final editing. All authors read and approved the final manuscript.

References

1. Drake JM, Rose C. The Shunt Book. Oxford: Blackwell Science; 1995.
2. Raimondi AJ. A unifying theory for the definition and classification of hydrocephalus. *Childs Nerv Syst.* 1994;10(1):2–12.
3. Rekate HL. The definition and classification of hydrocephalus: a personal recommendation to stimulate debate. *Cerebrospinal Fluid Res.* 2008;5(1):2.
4. Aronyk KE. The history and classification of hydrocephalus. *Neurosurg Clin N Am.* 1993;4(4):599–609.
5. McCullough DC. A history of the treatment of hydrocephalus. *Fetal Ther.* 1986;1(1):38–45.
6. Ames RH. Ventriculo-peritoneal shunts in the management of hydrocephalus. *J Neurosurg.* 1967;27(6):525–9.
7. Drake JM, Kulkarni AV, Kestle J. Endoscopic third ventriculostomy versus ventriculoperitoneal shunt in pediatric patients: a decision analysis. *Childs Nerv Syst.* 2009;25(4):467–72.
8. Hader WJ, Walker RL, Myles ST, Hamilton M. Complications of endoscopic third ventriculostomy in previously shunted patients. *Neurosurgery.* 2008;63(1 Suppl 1):ONS168–74; discussion ONS174–5.
9. Griebel R, Khan M, Tan L. CSF shunt complications: an analysis of contributory factors. *Childs Nerv Syst.* 1985;1(2):77–80
10. Lim, J., Tang, A. R., Liles, C., Hysong, A. A., Hale, A. T., Bonfield, C. M., Naftel, R. P., Wellons, J. C., III, & Shannon, C. N. (2019). The cost of hydrocephalus: a cost-effectiveness model for evaluating surgical techniques. *Journal of Neurosurgery: Pediatrics PED*, 23(1), 109-118.
<https://doi.org/10.3171/2018.6.PEDS17654>
11. Lam, S. K., Srinivasan, V. M., Luerssen, T. G., & Pan, I. (2014). Cerebrospinal fluid shunt placement in the pediatric population: a model of hospitalization cost. *Neurosurgical Focus FOC*, 37(5), E5.
<https://doi.org/10.3171/2014.8.FOCUS14454>
12. Gobierno de México, Secretaría de Salud, IMSS, ISSSTE. Catálogo de Intervenciones, Tratamientos, Servicios Auxiliares de Diagnóstico y Tarifas para el Intercambio de Servicios 2022. [Internet]. México; 2022. Disponible en: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.gob.mx/cms/uploads/attachment/file/703882/Cat_logo_de_intervenciones_con_tarifas_2022.pdf. Accedido 24 Abr. 2024.

13. Fernández-Méndez R, Richards HK, Seeley HM, Pickard JD, Joannides AJ; UKSR collaborators. Current epidemiology of cerebrospinal fluid shunt surgery in the UK and Ireland (2004–2013). *J Neurol Neurosurg Psychiatry*. 2019;90(7):747–54.
14. UK Shunt Registry [Internet]. London: Society of British Neurological Surgeons; [cited 2021 Jun 21]. Available from: <https://www.sbns.org.uk/index.php/audit/shunt-registry/>
15. Bowman RM, McLone DG, Grant JA, Tomita T, Ito JA. Spina bifida outcome: a 25-year prospective. *Pediatr Neurosurg*. 2001;34(3):114–20.
16. Christian EA, Melamed EF, Peck E, Krieger MD, McComb JG. Surgical management of hydrocephalus secondary to intraventricular hemorrhage in the preterm infant. *J Neurosurg Pediatr*. 2016;17(3):278–84.
17. Wellons JC 3rd, Shannon CN, Holubkov R, Riva-Cambrin J, Kulkarni AV, Limbrick DD Jr, et al. Shunting outcomes in posthemorrhagic hydrocephalus: results of a Hydrocephalus Clinical Research Network prospective cohort study. *J Neurosurg Pediatr*. 2017;20(1):19–29.
18. Kieran MW, Walker D, Frappaz D, Prados M. Brain tumors: from childhood through adolescence into adulthood. *J Clin Oncol*. 2010;28(32):4783–9
19. Simon TD, Riva-Cambrin J, Srivastava R, et al. Hospital care for children with hydrocephalus in the United States: utilization, charges, comorbidities, and deaths. *J Neurosurg Pediatr*. 2008;1(2):131–
20. Limbrick DD Jr, Rozzelle CJ, Strahle J, et al. Hydrocephalus Clinical Research Network. Shunt treatment of posthemorrhagic hydrocephalus: a prospective cohort study. *J Neurosurg Pediatr*. 2015;16(1):1–11.
21. Kulkarni AV, Drake JM, Lamberti-Pasculli M. Cerebrospinal fluid shunt infection: a prospective study of risk factors. *J Neurosurg*. 2001;94(2):195–201.
22. Smith ER, Butler WE, Barker FG 2nd. In-hospital mortality rates after ventriculoperitoneal shunt procedures in the United States, 1998 to 2000: relation to hospital and surgeon volume of care. *J Neurosurg*. 2004;100(2 Suppl Pediatrics):90–7.
23. Wu Y, Green NL, Wrensch MR, Zhao S, Gupta N. Ventriculoperitoneal shunt complications in California: 1990 to 2000. *Neurosurgery*. 2007;61(3):557–62; discussion 562–3.
24. Stein SC, Guo W. Have we made progress in preventing shunt failure? A critical analysis. *J Neurosurg Pediatr*. 2008;1(1):40–7.
25. Parker SL, McGirt MJ, Murphy JA, Megerian JT, Stout M, Engelhart L. Cost savings associated with antibiotic-impregnated shunt catheters in the treatment of adult and pediatric hydrocephalus. *World Neurosurg*. 2015;83(3):382–6.

Figures

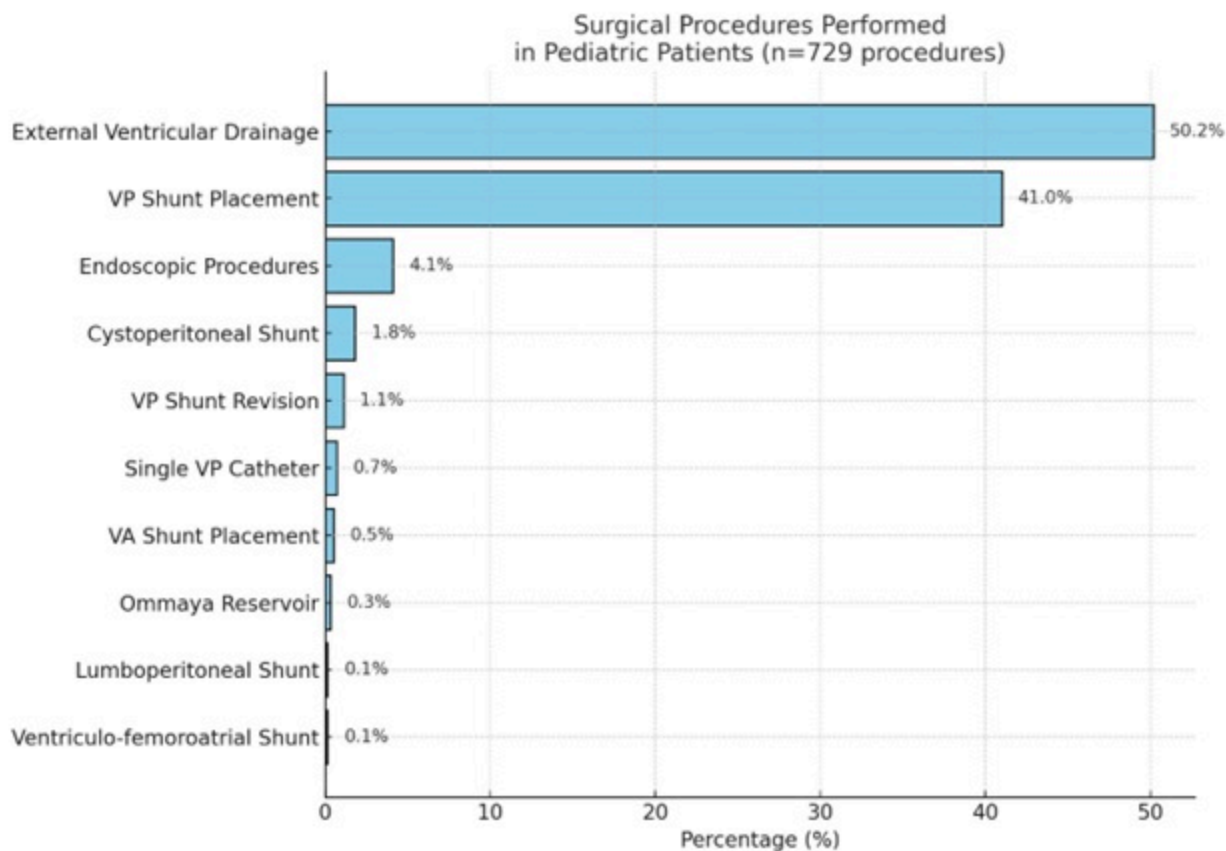


Figure 1

Types of Surgical Procedures Performed for CSF Diversion.

Horizontal bar graph showing the percentage distribution of surgical interventions: external ventricular drainage (50.2%), ventriculoperitoneal shunt placement (41.0%), endoscopic procedures (4.1%), cystoperitoneal shunt placement (1.8%), and others (<2%).

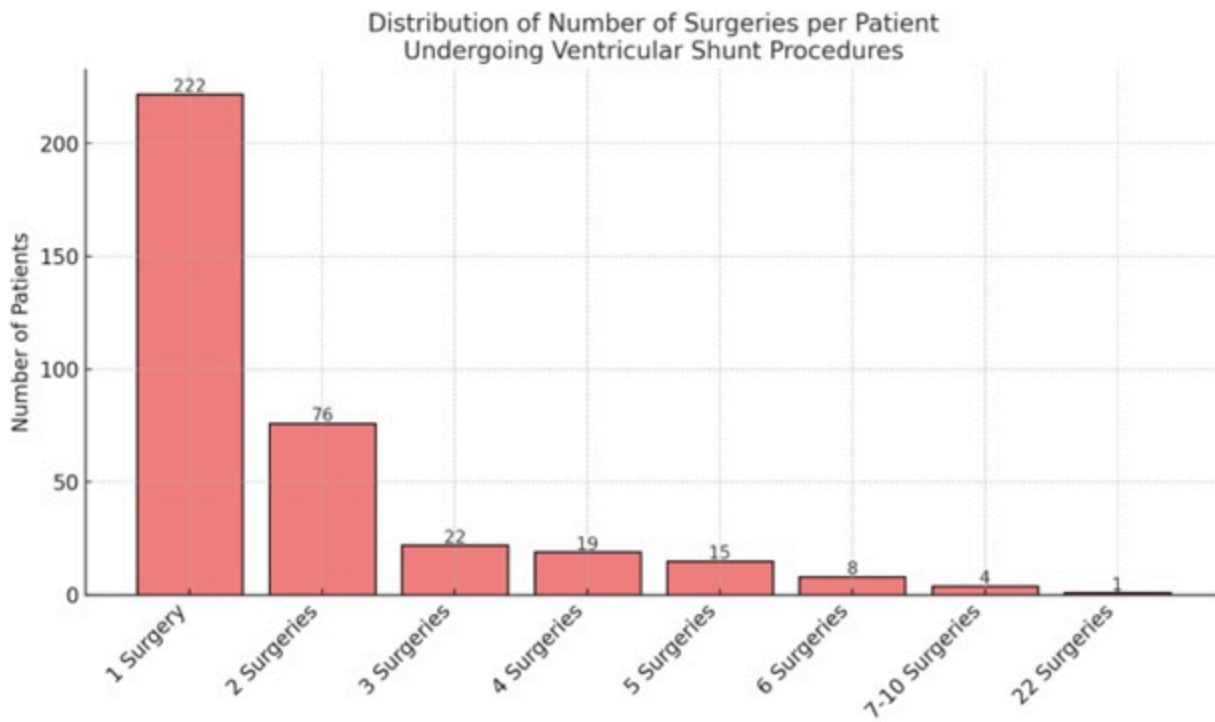


Figure 2

Number of Surgeries Required per Patient.

Bar graph representing the distribution of the number of surgeries per patient. While 59.8% of patients required only one surgery, 40.2% required two or more, with some undergoing up to 22 procedures.

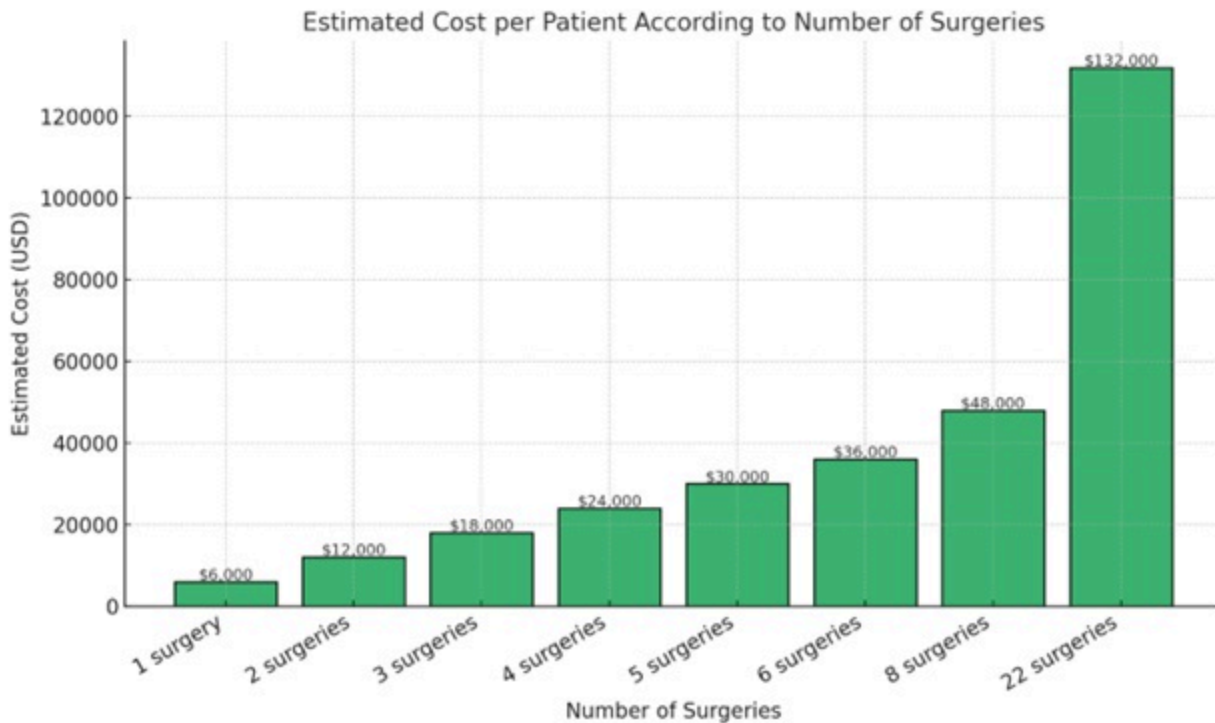


Figure 3

Estimated Cost per Patient According to the Number of Surgeries.

Bar graph displaying the estimated cumulative cost per patient based on the number of surgical interventions, assuming an average cost of \$6,000 USD per surgery. Costs ranged from \$6,000 USD for a single procedure up to \$132,000 USD for patients requiring 22 surgeries.