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Original Article

Prognostic and morphological factors in pediatric cerebellar contusions

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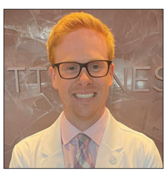

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ABSTRACT

Background: Although uncommon, cerebellar contusions are associated with significant morbidity and mortality. Literature is lacking in the prognostic and morphological factors relating to their clinical picture and outcomes, especially within children. The objective of this study is to evaluate prognostic and anatomic factors in the clinical picture of cerebellar contusions, including effacement of the 4th ventricle and cisterna magna.

Methods: This is a retrospective chart review over 11 years across two medical centers. Patients included were under 18 years who presented with a cerebellar contusion. Patients were stratified within the study group based on discharge Glasgow outcome scale (GOS) and reviewed for prognostic factors contributing to outcome. Mid sagittal area of the 4th ventricle and cisterna magna were measured using magnetic resonance imaging and compared within the groups.

Results: A total of 21 patients met the study criteria, of which 16 (76.2%) were male, with an average patient age of 8.65 years. Poor outcome at discharge (GOS <4) was associated with decreased admission Glasgow coma scale (P = 0.003), admission motor response (P = 0.006), pupil reactivity (P = 0.014), presence of concomitant subarachnoid hemorrhage (P = 0.010), contusion volume (P < 0.001), and decreased area of the cisterna magna (P = 0.012). Patients with poor outcomes were also more likely to require surgical intervention (P = 0.042).

Conclusion: There are multiple prognostic factors associated with the overall outcome following cerebellar contusions. The rate of good outcomes in this study was superior to that in previous studies in adults.

Keywords: Cerebellar contusions, Intraparenchymal hemorrhage, Pediatrics, Posterior fossa, Traumatic brain injury

INTRODUCTION

Traumatic brain injury (TBI) represents the leading cause of pediatric death and disability annually, with estimates of 70–75 hospitalizations/100,000.[2] Within the subsets of TBI, cerebellar contusions make up a small proportion of these injuries, as they are relatively uncommon.[8,19] Previously reported incidence rates of cerebellar contusions are <1% of head injuries, with some estimates as low as 0.4%.[17,18] Despite their relative rarity, cerebellar contusions are associated with substantial morbidity and mortality, with estimates of poor clinical outcomes ranging between 20% and 100%, with an average of 60%.[1,5,8,14,15] These injuries result in a myriad of long-term sequelae that have a significant impact on patients' quality of life, including the resultant development of deficits in speech, attention, and fine motor movement.[15] Due to their relative rarity, the existing literature is limited on the factors predicting and influencing the clinical picture and long-term outcomes of patients sustaining cerebellar contusions.[1,14] Previous studies have demonstrated that the best indicator of outcomes following cerebellar contusions is the patients' Glasgow Coma Scale (GCS) scores on admission. Other prognostic factors include effacement of the basal cisterns, 4th ventricular compression, intraventricular hemorrhage, the size and location of the contusion, concomitant subarachnoid hemorrhage (SAH), and the presence of associated cerebral injury.[1,4,14,15]

Due to the low incidence of cerebellar contusions, few studies have endeavored to establish prognostic factors in patients sustaining cerebellar contusions. These studies have historically generated small sample sizes with limited statistical power.[1,4,14] Furthermore, these studies predominantly investigate the adult population, resulting in limited external validity in applying their findings to a pediatric population. The existing literature investigating cerebellar contusions in pediatric populations primarily consists of case reports/series and most studies focused on adult patients, with only a limited number of pediatric patient outcomes included.[8,14] However, there is a notable absence of morphologic studies investigating the 4th ventricle and cisterna magna in the context of cerebellar contusions. As a result, there is a dearth of research examining prognostic and morphological factors contributing to the clinical picture and outcomes in cerebellar contusions, especially within pediatric populations. This study aims to evaluate prognostic clinical and morphological factors in pediatric patients with cerebellar contusions.

MATERIALS AND METHODS

Study population

Following formal approval from the Institutional Review Board, we performed a retrospective analysis of patients who presented to the emergency department (ED) with cerebellar contusions from the years 2012 to 2022. This study was performed at two medical centers, one of which is an academic institution with a level 1 trauma center that acts as a tertiary care facility and the other with a level 2 trauma center. Patients were included in the study if they were younger than 18 years of age on sustaining cerebellar contusion(s). To gather the list of patients meeting study criteria, the IT departments were asked to run a list of all patients who presented during these years with a TBI and/or basilar skull fractures. Of the lists provided, we manually screened for all patients with cerebellar contusions based on magnetic resonance imaging (MRI) imaging. Patients were excluded if they had incomplete or missing data.

Data acquisition

Due to the retrospective nature of this study, all data were gathered through electronic medical records, including physician notes, nurse notes, operative notes, and imaging studies. Demographic data obtained included patient age, sex, and mechanism of injury. Further, data were obtained regarding patients' presentation status, including admission GCS, motor response, pupil reactivity, and symptoms at presentation. Subsequently, related data were obtained from imaging studies, including the type of contusions, number of contusions present, associated diffuse axonal injury, concomitant cerebral injury, location of contusion (central vs hemispheric), concomitant SAH, the presence of hydrocephalus, intraventricular hemorrhage, and whether the contusion progressively increased in size. Data were collected on whether surgical operations were warranted and the method used for surgical evacuation.

In addition to the data mentioned above collected, measurements were also taken of the 4th ventricular and cisterna Magna's mid-sagittal area, and the volume of the contusions. All measurements were obtained thrice using MRI under the supervision of the attending neurosurgeon. Initial MRI imaging was obtained around the 24 h mark with no MRI being obtained later than the 36-h mark. The 4th ventricular and cisterna Magna's areas were measured in the mid-sagittal plane utilizing the area measuring tool within the imaging program [Figure 1]. The area of the 4th ventricle

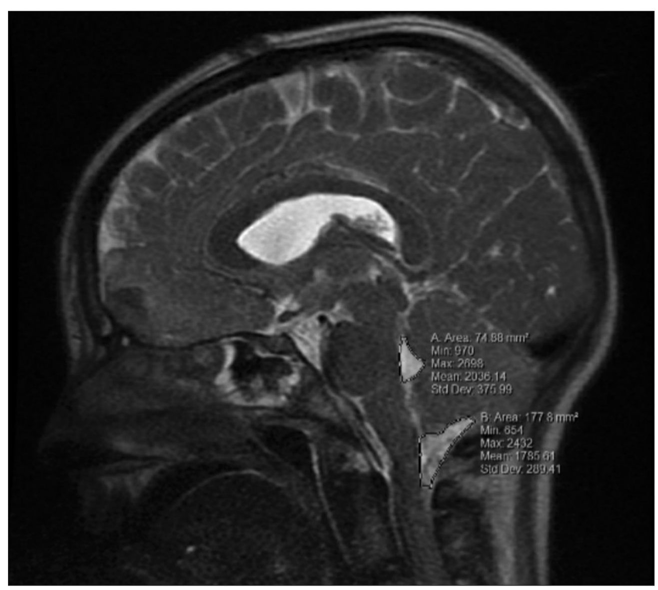

Figure 1: Sagittal T2-weighted magnetic resonance imaging demonstrating measurement of the 4th ventricle and cisterna magna of a patient with a cerebellar contusion.

and the cisterna magna were documented separately, then added together and documented as the free water space. Contusion volume was then measured primarily using the axial plane for measurement. The axial area of the contusion was measured using the ABC method previously reported [Figure 2].[11] The procedure for measuring the area of the 4th ventricle, cisterna magna, and free water space was then repeated on the patient's follow-up imaging, and the time to follow-up was documented. Finally, the free water space from the initial MRI was subtracted from the follow-up MRI and documented as the free water change.

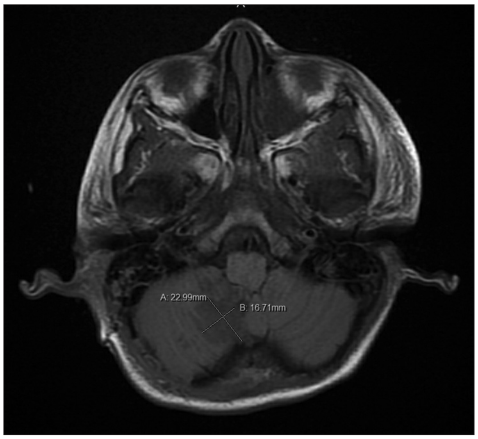

Figure 2: Axial T1-weighted magnetic resonance imaging demonstrating the measurements of the cerebellar contusion utilizing the ABC method.

The primary outcome of the study was the discharge Glasgow outcome scale (GOS). A GOS of 4 or 5 was considered a good outcome, while a GOS of 1, 2, or 3 was considered a poor or bad outcome. Secondary outcome measures included total length of stay (LOS), intensive care unit (ICU) LOS, and follow-up GOS, which was obtained from follow-up neurosurgical clinic notes.

Statistical analysis

Statistical analyses are based on inferential statistics with an emphasis on hypothesis testing using a significance level of $\alpha = 0.05$, two-sided *P*-values, and independent samples. Analyses included partitioning subjects into two independent groups and then comparing all other variables across groups. Binary and multilevel nominal variables are summarized using counts and percentages with differences across groups tested using Fisher's test and the standardized mean difference (SMD) as effect size. Ordinal level variables are summarized using the median and interquartile range (IQR) with differences across groups testing using the Mann–Whitney U-test with Cliff's δ as effect size. Interval level variables are summarized as mean

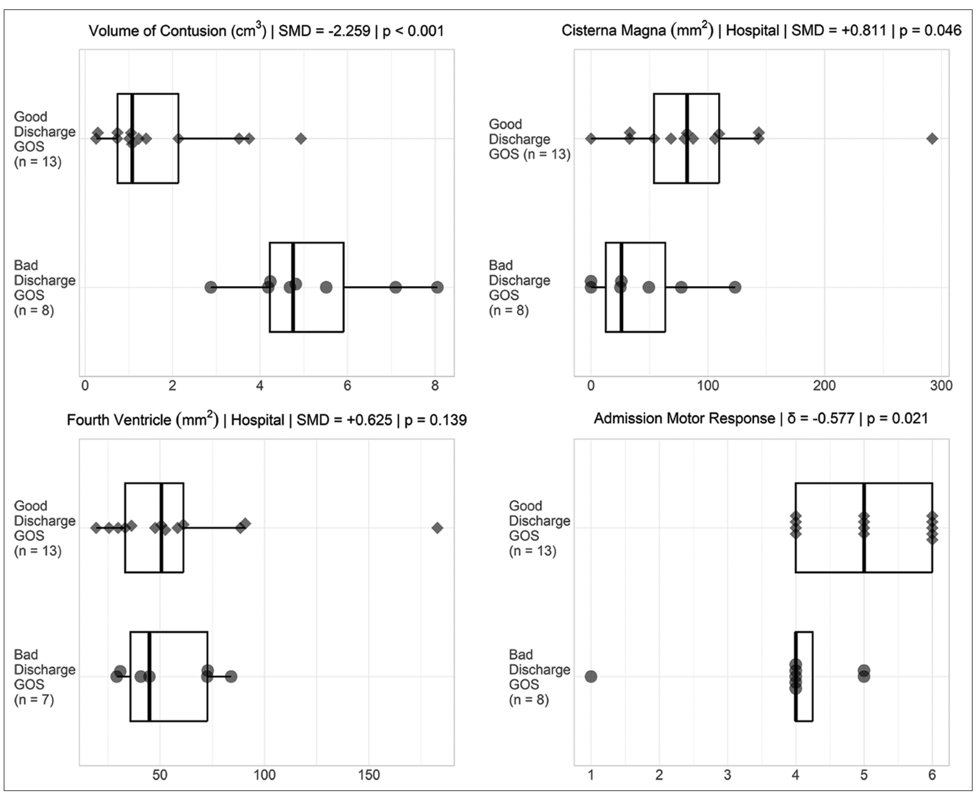

Figure 3: Morphologic factors between the good outcome and bad outcome cerebellar contusion patients. SMD: Standardized mean difference

and standard deviation (SD) with differences across groups tested using the permutational unequal variance *t*-test based on 1000 randomizations and using the SMD as effect size. Associations between interval and ordinal level variables are tested using the Spearman correlation, and associations between binary and ordinal variables are tested using the exact Cochrane-Armitage test of trend with Freeman's θ as effect size. Hypothesis tests and descriptive statistics exclude any missing values. To simplify the presentation and interpretation of results, no adjustments to *P*-values to control the false discovery rate or the family-wise error rate have been made, and no multivariate analyses have been used. This project does not involve parameter estimation, so that confidence intervals for effect sizes and population parameters are not provided. The sample sizes were determined based on data availability and exclusion criteria so that no *a priori* power analyses were conducted. To aid in the interpretation of non-significant *P*-values, Supplementary Figure 1 provides *post hoc* power analyses for Fisher's test, the Mann–Whitney U-test, the *t*-test, and the correlation test corresponding to the sample sizes of this project. Supplementary Table 1 provides interpretations of the effect sizes used in this project. Data management was performed using Microsoft Excel (Microsoft, Redmond, Washington) and statistical analyses were performed with R 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Demographics

A total of 4238 patient ED records were searched and 27 patients presented during the period with cerebellar contusions. Of these patients, 21 were included in the study, as the others did not meet the inclusion criteria. The mean age was 8.65 (SD = 6.53), and 76.2% (n = 16) were male. The most common reason for the presentation was a motor vehicle collision (MVC) (52.4%), followed by a fall from height/blow to the head (33.3%), gunshot wound-associated injury (9.5%), and nonaccidental trauma (4.8%). Injuries from the gunshot wound were not caused by direct trauma from a penetrating injury. The median GCS on admission was 7.0 (IQR 4.0 [10–6]), with a median best-admission motor response of 5.0 (IQR = 1.0 [4–5]). Contusions were present in the midline in 52.4% (n = 11) of patients, in the lateral hemispheres in 38.1% (n = 8) of patients, and in the tonsils in 9.5% (n = 2) of patients. Two contusions were found in 38.1% (n = 8), while the rest of the patients had one. The mean GOS at discharge was 3.8 (SD = 1.2). The average follow-up was 8.5 months (SD = 9.2), and the average GOS was 4.7 (SD = 0.5). There were two fatalities in the patient group, one of whom was injured in an MVC and the other injured with a gunshot wound. They both presented to the ED with GCS scores of 5 and 7, respectively. About 19.0% (n = 4) of patients underwent posterior fossa decompression and hematoma evacuation.

Predictors of outcome

Of the 21 patients with cerebellar contusions, 13 had a good outcome at discharge. Patients with bad outcomes at discharge more commonly presented with lower GCS (P = 0.030), lower admission motor response (P = 0.021), worse pupil reactivity (P = 0.029), presence of concomitant SAH (P = 0.047), larger contusion volume ($P < 0.001$), and diminished area of the cisterna magna (P = 0.046) [Figure 3]. Patients with poor outcomes also required a longer total LOS and a longer ICU LOS (P = 0.002 and P = 0.009, respectively) [Table 1]. Patients with poor outcomes at discharge were also more likely to have required surgical intervention (P = 0.042).

DISCUSSION

Compared to intracerebral contusions, cerebellar contusions are less common and have previously reported incidence rates of <1.0%, with ranges between 0.4% and 0.8%.[1,4,5,9,13,14,17,18] Cerebellar contusions have been described to be less common in children than adults.[12,14] This study had an overall incidence rate of cerebellar contusions in pediatric patients of 0.6%, which is comparable to previously reported literature. The decreased area of the cisterna magna and the size of the contusion were two posterior morphological factors that were heavily correlated to the outcome.

Previous studies have explored the predictors of outcome in patients following cerebellar contusions in adults.[1,14] Bhardwaj *et al*. found that compression of the 4th ventricle, effacement of basal cisterns, SAH, contusion volume and location, admission GCS, associated intracranial hematomas, increasing age, and female sex were negatively correlated with outcome.[1] Unlike Bhardwaj *et al*., we did not find an associated intracranial lesion, age, or sex to be associated with outcome. This could be due to our sample age being considerably younger, as all our patients were under the age of 18, whereas Bhardwaj *et al*.'s cohort only included one patient under 18 (age of 12). Furthermore, their patient population had a much wider age range, which could have contributed to the effect age has on outcomes in adults.[1] Pandey *et al*. found that the age at presentation, best motor response, the severity of the injury, GCS at admission, effacement of basal cisterns, 4th ventricular compression and hemorrhage, presence of hydrocephalus, SAH, and volume of the contusion were all associated with outcome.[14] Our results were similar with pupil reactivity, GCS, admission motor response, concomitant SAH, compression of the cisterna magna, and contusion size as prognostic factors for outcome. Both previous studies identified basal cisterns and 4th ventricle size as being inversely correlated to worse

Table 1: Comparison of factors for good and bad outcomes.

Description	Bad GOS (*n*=8)	Good GOS (*n*=13)	Effect size	*P*-value
Sex (males)[a]	5/8 (62.5)	11/13 (84.6)	0.518	0.325
Age (years)[b]	9.83 (6.49)	7.92 (6.70)	−0.288	0.547
Method of injury				
Motor vehicle collision	4/8 (50.0)	7/13 (53.8)	0.677	0.712
Known accidental	2/8 (25.0)	5/13 (38.5)		
Nonaccidental	1/8 (12.5)	0/13 (0.0)		
Unknown	1/8 (12.5)	1/13 (7.7)		
Admission GCS[c]	8.0 (4.0)	6.0 (0.5)		0.030
Concomitant cerebral injury	7/8 (87.5)	8/13 (61.5)	−0.624	0.336
Number of contusions	1.25 (0.46)	1.46 (0.52)	0.421	0.177
DAI	4/8 (50.0)	1/13 (7.7)	−1.056	0.047
4th ventricle intraventricular Hemorrhage	0/8 (0.0)	1/13 (7.7)	0.408	1.000
Presence of associated SAH	4/8 (50.0)	1/13 (7.7)	−1.056	0.047
HCP	0/8 (0.0)	1/13 (7.7)	0.408	1.000
Evolving contusion	2/8 (25.0)	1/13 (7.7)	−0.481	0.531
Surgically managed	3/8 (37.5)	1/13 (7.7)	−0.763	0.253
Volume of contusion (cm^3)	5.18 (1.67)	1.7 (1.46)	−2.259	<0.001
Admission area of cisterna magna (mm^2)	43.04 (44.69)	94.83 (72.7)	0.811	0.046
Admission area of 4th ventricle (mm^2)	53.63 (22.38)	59.77 (42.97)	0.167	0.742
Free water space at the presentation	96.67 (54.66)	154.6 (108.86)	0.625	0.139
Follow-up area of cisterna magna (mm^2)	134.76 (116.89)	196.01 (112.22)	0.537	0.336
Follow-up area of 4th ventricle (mm^2)	112.68 (66.05)	89.2 (47.57)	−0.426	0.454
Follow-up free water space	247.45 (125.58)	285.2 (151.58)	0.265	0.618
Follow-up free water change	150.78 (93.09)	128.41 (56.07)	−0.311	0.577
Length of time to follow-up MRI (months)	11.17 (10.15)	7.21 (8.88)	−0.423	0.479
ICU length of stay (days)	19.5 (11.22)	6.23 (3.81)	−1.78	0.009
Total length of stay (days)	25.67 (11.31)	9.08 (4.72)	−2.121	0.002

[a]Categorical variables summarized as counts (%) with SMD as effect size. [b]Interval level variables summarized as mean (standard deviation) with SMD as effect size. [c]Ordinal level variables summarized as median (interquartile range) with Cliff's δ as effect size. GOS: Glasgow outcome scale, MRI: Magnetic resonance imaging, ICU: Intensive care unit, SAH: Subarachnoid hemorrhage, SMD: Standardized mean difference, DAI: Diffuse axonal injury, GCS: Glasgow coma scale, HCP: Hydrocephalus

outcomes. Statistically, we only found cisterna manga size to correlate with outcome and not 4th ventricle size.

The location of the hematoma has previously been shown to be related to the outcome following cerebellar contusions. Contusions have been considered either peripheral or central, with the latter being correlated to worse outcomes. This is thought to be due to the location of the deep cerebellar nuclei.[1,18] In our study, however, the location of the contusion was not significantly related to patient outcome. This discrepancy could potentially be attributed to the higher neuroplasticity observed in younger patients compared to adults or the limited sample size in our study.[7] Although evolving or delayed contusions have previously been associated with worse outcomes, this was not observed in our study.[5,13]

There is a broad range of symptoms that patients have previously presented with following cerebellar contusions. These can be classified as symptoms of cerebellar dysfunction or symptoms of increased intracranial pressure (ICP). Cerebellar dysfunctions include dysdiadochokinesis, nystagmus, hypotonia, ataxia, dysmetria, tremor, and vertigo. Typical signs of high ICP include headache, decreased arousal/altered sensorium, vomiting, and pupil irregularity.[8,15] There have been a few rare reported cases of cerebellar mutism in pediatric patients with cerebellar contusions.[3,10] This present study differed from the previously reported studies as 52.4% (n = 11) of patients were unresponsive at admission, and another 23.8% (n = 5) were somnolent but arousable to painful stimuli. This could correlate to a higher severity of head injuries.

The historical outcome of patients who have sustained cerebellar contusions is not favorable. Many studies have high mortality rates and a low number of good outcomes following surgery. Mortality rates are typically reported around 40%, whereas poor outcomes are usually reported between 20% and 100%, with an average of 60%.[1,5,18] Pandey *et al.* report a rate of good outcome (GOS of 4 or greater) of 82.6% and a mortality rate of 8.7 %. However, it is important to note that these reflect only the conservatively managed cases and not the cases of patients undergoing surgical evacuation and decompression. The rates of good outcomes in our study were 61.9% (n = 13) at discharge and 85.7%

(*n* = 18) at follow-up. Moreover, we had a mortality rate of 9.5% (*n* = 2), which is similar to Pandey *et al.*, and lower than the commonly reported mortality rates.[14,15]

Recently, conservative management has become popular in the care of patients with cerebellar contusions. Guidelines suggest that surgery is appropriate when the contusion is >3 cm in diameter or 15 mL in size, compression of cisterna magna or 4th ventricle is present, and/or acute hydrocephalus or associated epidural/subdural hematomas in the posterior fossa are present.[6,16] Low GCS is also a factor in deciding between surgical management or conservative management.[6,15,16] In our study, 19.0% (*n* = 4) of patients required surgical intervention. These patients all presented with a contusion size between 2 and 3 cm and a GCS of <6 at the time of surgery. Of those who underwent surgery, one died, and one had a good outcome at discharge; however, by follow-up, all three survivors had a good outcome. The rest of the patient population underwent conservative management, providing more evidence for the success of conservative management in cerebellar contusions, specifically in the pediatric population.

In the literature regarding cerebellar contusions, few studies and case reports present that compression of the 4th ventricle and effacement of the basal cisterns are correlated with worse outcomes.[1,5,14,15,20] One issue with this classification is that it is subjective and binary, indicating that slight compression or effacement may not be taken into consideration. Furthermore, there is a lack of quantification of the compression or effacement, and the methods sections in these studies do not mention how a determination of compression or basal cistern effacement was made. To evaluate this nuance, we added a morphological component to this study to quantify the compression of the 4th ventricle and effacement of the cisterna magna. All patients who had a cerebellar contusion had some degree of compression of their 4th ventricle and cisterna magna.

Limitations

A limitation of this study is the retrospective nature, which can induce bias. Furthermore, though the sample size is comparable to existing literature, our study's power is limited by the small sample size of 21 patients. Another limitation of this study was the time to initial MRI after presentation. All patients presented in this study had an MRI within the first 36 hours of admission; however, a uniform timing of MRI would have been optimal. Due to the nature of TBI, patient presentations were heterogenous, with multiple patients presenting with concomitant cerebral contusions. Finally, only a single patient had an MRI before the injury; therefore, follow-up MRIs were used for comparison.

CONCLUSION

In pediatric patients with cerebellar contusions, the decreased size of their cisterna magna, reduced pupil reactivity, decreased GCS, decreased admission motor response, and concomitant SAH have all shown a negative correlation with discharge outcome. Taken together, these components serve as prognostic factors. Pediatric patients demonstrated a good overall outcome following both surgical and conservative management. Future research is warranted further to explore these associations and their potential clinical applications.

Data availability statement

All data generated or analyzed during this study are included in this article. Further, enquiries can be directed to the corresponding author.

Ethical approval

The Institutional Review Board has waived the ethical approval for this study.

Declaration of patient consent

Patient's consent are not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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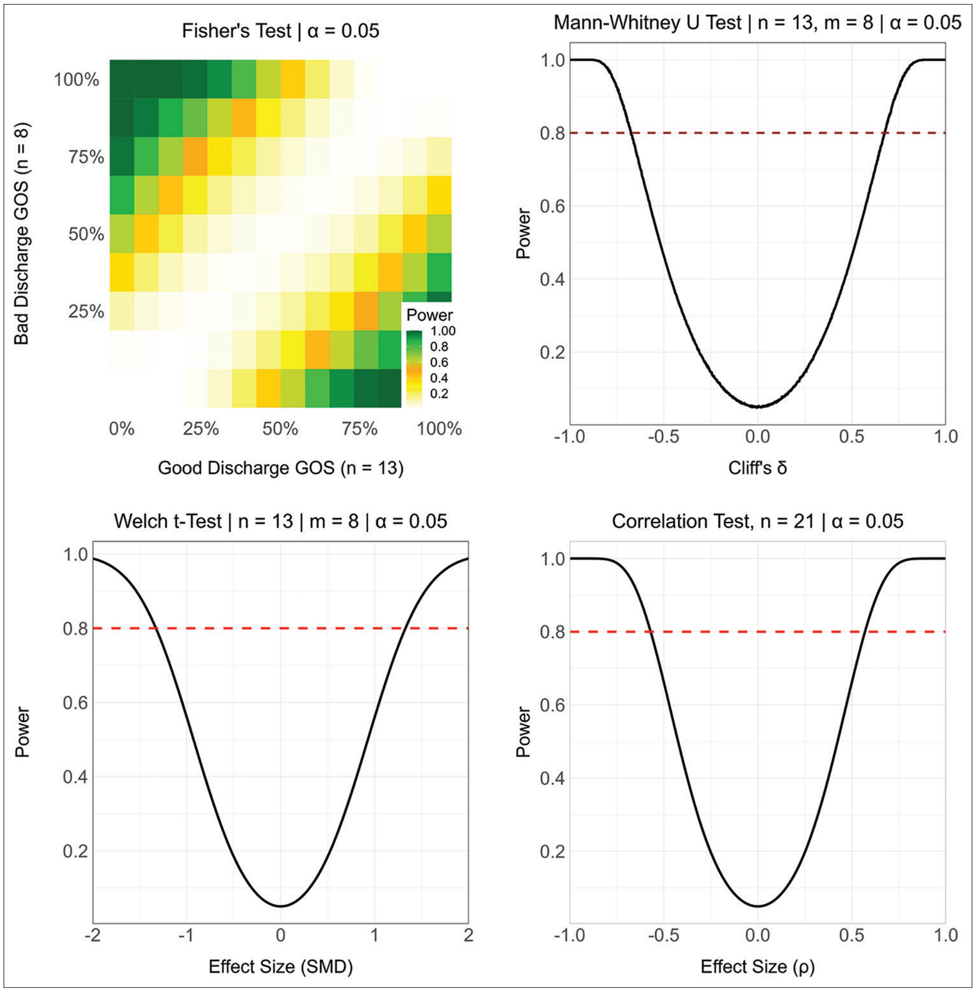
SUPPLEMENTARY



Supplementary Figure 1: *Post-hoc* power analysis for Fisher's test, the Mann-Whitney-U test, *t*-Test, and correlation test.

Supplementary Table 1: Effect size.

Effect Size	Lower Bound	Upper Bound	Interpretation
Cliff's δ			
	0.000	0.147	Negligible
	0.148	0.330	Small
	0.331	0.474	Moderate
	0.475	1.000	Large
Spearman ρ			
	0.00	0.100	Negligible
	0.101	0.300	Small
	0.301	0.500	Moderate
	0.501	1.000	Large
SMD			
	0.000	0.199	Negligible
	0.200	0.499	Small
	0.500	0.725	Moderate
	0.800		Large
Freeman θ			
	0.000	0.147	Negligible
	0.148	0.330	Small
	0.331	0.474	Moderate
	0.475	1.000	Large