

Intracranial Aneurysm Surgery among the Hispanic Puerto Rican Population: A 25-Year Single-Surgeon Experience

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Objective: This study aimed to describe a cohort of Hispanic Puerto Rican patients with intracranial aneurysms who underwent surgery by a single surgeon at an academic center over a 25-year period.

Methods: A retrospective study was performed using the electronic database of the Neurosurgery Program at the University of Puerto Rico, Medical Sciences Campus, to identify patients whom the author operated on for the treatment of an intracranial aneurysm from 1996 through 2020. The study included all Hispanic patients who underwent open surgical treatment for an intracranial aneurysm by the author during the study period.

Results: Over 25 years, 255 patients underwent surgery for the treatment of intracranial aneurysms. Seventy-one percent of patients were female and 29% were male, with a female-to-male ratio of 2.4:1. The median age was 55 years (interquartile range, 46–65 years). Eighty-seven percent of the patients had surgery for a ruptured aneurysm and 13% for an unruptured aneurysm. The most frequent locations for the aneurysms were the anterior communicating artery (33.3%) and the posterior communicating artery (32.5%). Anterior communicating artery aneurysms were more frequent in men, whereas posterior communicating artery aneurysms were more frequent in women. Postoperative rebleeding from an unclipped or a partially clipped aneurysm was significantly associated with death.

Conclusion: In this single-surgeon surgical cohort from Puerto Rico, there was a substantial female predominance among patients with intracranial aneurysms. More than half of the patients treated for aneurysms were aged 50–69 years.

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Approximately 1% to 2% of the population has a risk of developing an intracranial aneurysm (IA) during their lifetime (1). Unruptured IAs have a calculated overall prevalence of 3.2% (2). The incidence of ruptured aneurysms varies across countries, with an estimated rate of 9–10.5 per 100,000 person-years (3,4). The in-hospital mortality for aneurysmal subarachnoid hemorrhage (SAH) in the US approaches 25% (5). Ruptured aneurysms are treated with open surgical clipping or endovascular obliteration to prevent rebleeding. Unruptured aneurysms are often treated to avoid potential future rupture. Hispanic ethnicity has been identified as a factor associated with increased incidence of unruptured aneurysms and increased risk of aneurysm rupture (6-10). Despite the reported association between Hispanic ethnicity and IAs, detailed information on IAs in the Hispanic population of Puerto Rico remains limited. Only three published studies have evaluated IA cohorts within Puerto Rico. Two studies with a small number of patients were published more than 50 years ago (11,12). A more recent 2-year investigation compared patients with non-aneurysmal SAH and those with aneurysmal SAH (13). The current study aimed to investigate Hispanic patients in Puerto Rico who underwent open surgery for intracranial IAs over a 25-year period by a single surgeon at an academic center and compare the findings with the global literature.

Methods

A retrospective study was performed using the electronic database of the Neurosurgery Program of the University of Puerto Rico, Medical Sciences Campus, to identify patients who underwent open surgery for treatment of an IA by a single surgeon at an academic center from 1996 through 2020. Only Hispanic patients with an IA who received open surgical treatment by the author during the study period were included. Patients whose aneurysms were treated exclusively using endovascular techniques were excluded. For each identified patient, the following data were collected: age, sex, presence of SAH, aneurysm location, presence of multiple aneurysms, the post-bleeding day on which surgery was performed, the Hunt and Hess scale grade, and postoperative complications. Although the Hunt and Hess and the World Federation of Neurosurgical Societies scales are the

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most frequently used grading systems for SAH, this study used only the Hunt and Hess scale because it was consistently recorded throughout the study period (14,15).

Descriptive statistics were used to report frequencies, percentages, and medians. Continuous variables with non-normal distribution were reported as medians, with interquartile range (IQR), at the 25th-75th percentile. Categorical variables were presented as numbers with percentages. Comparisons between aneurysm location and sex and associations between complications and mortality were evaluated using Fisher's exact test. A significance level of $P < .05$ was used. The study was approved by the Institutional Review Board of the University of Puerto Rico, Medical Sciences Campus (protocol number 2402189250).

Results

The study reviewed 255 patients who underwent surgical treatment of an IA by a single surgeon over a 25-year period. Seventy-one percent of patients in the study cohort were female, resulting in a 2.4:1 female-to-male ratio (Table 1). The median age of the patients was 55 years (IQR, 46–65 years; range, 17–87 years). Female patients had a median age of 55 years (IQR, 48–65 years), and male patients had a median age of 52.5 years (IQR, 43–57 years). Fifty-seven percent of the treated aneurysms occurred in patients aged 50–69 years (Figure 1). Male patients exhibited a standard bell-shaped age distribution, with a peak in the sixth decade (Figure 2). However, female patients presented two age peaks, at 50–55 years and 65–70 years, with the highest in the seventh decade (Figure 3). The female-to-male ratios were 2:1 in the third decade, 1.3:1 in the fourth decade, 1.8:1 in the fifth decade, 2.5:1 in the sixth decade, and 3.6:1 in later decades. Eighty-seven percent of the patients underwent surgery for a ruptured aneurysm, whereas 13% underwent surgery for an unruptured aneurysm. Among the patients with ruptured aneurysms, the median Hunt and Hess grade was 1 (IQR, 1–2). Fifty-seven percent had a Hunt and Hess grade 1, 21% grade 2, 16% grade 3, and 6% grade 4. Patients with ruptured aneurysms underwent surgery at a median of 5 days post-bleeding (IQR, 3–19). Multiple aneurysms were identified in 25 patients (9.8%).

The most frequent locations of the aneurysms were the anterior communicating artery (AcomA) (33.3%) and posterior communicating artery (PcomA) (32.5%) (Table 2). Middle cerebral artery (MCA) bifurcation aneurysms were identified in 18.4% of the patients. AcomA aneurysms were more frequent in men (49%) than in women (27%) ($P < .05$). In contrast, PcomA aneurysms were more frequent in women (40%) than in men (13%) ($P < .01$). Superior hypophyseal artery, internal carotid dorsal wall, and posterior inferior cerebellar artery aneurysms were identified

Table 1. Baseline characteristics of 255 patients who underwent surgery for an intracranial aneurysm

Variable	n (%) or Median (IQR)
Age (median)	55 (IQR 46–65)
Male	74 (29%)
Female	181 (71%)
Ruptured aneurysm	221 (87%)
Unruptured aneurysm	34 (13%)
Multiple aneurysm	25 (9.8%)
Hunt and Hess grade (median)	1 (IQR 1–2)
Day of surgery after rupture (median)	5 (IQR 3–19)
Symptomatic cerebral vasospasm	48 (18.8%)
Complications	54 (21.2%)
Deaths	22 (8.6%)

IQR, interquartile range

only in female patients; however, the number of cases was too small to conduct statistical tests or estimate associations. Middle cerebral artery aneurysms were more frequent in men (23%) than in women (17%), but the difference was not significant ($P = .387$). The number of patients with aneurysms at the internal carotid artery bifurcation and in the pericallosal, anterior choroidal, anterior temporal, and ophthalmic arteries was too small to establish sex-related differences.

Aneurysm location was analyzed separately for ruptured and unruptured aneurysms, and the distribution was compared across sexes. Among the patients with ruptured aneurysms, 70% were female and 30% were male, yielding a 2.3:1 female-to-male ratio. Ruptured AcomA aneurysms tended to be more frequent in men (48%) than in women (32%), although the difference was not significant ($P = .166$), whereas ruptured PcomA aneurysms were more frequent in women (39%) than in men (13%) ($P < .01$). Among patients with unruptured aneurysms, 79% were female

Figure 1. Age distribution of the entire cohort (n = 255)

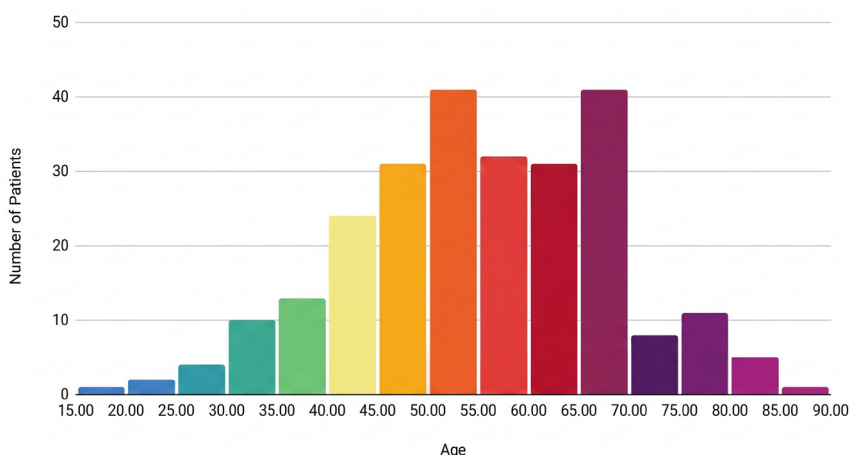
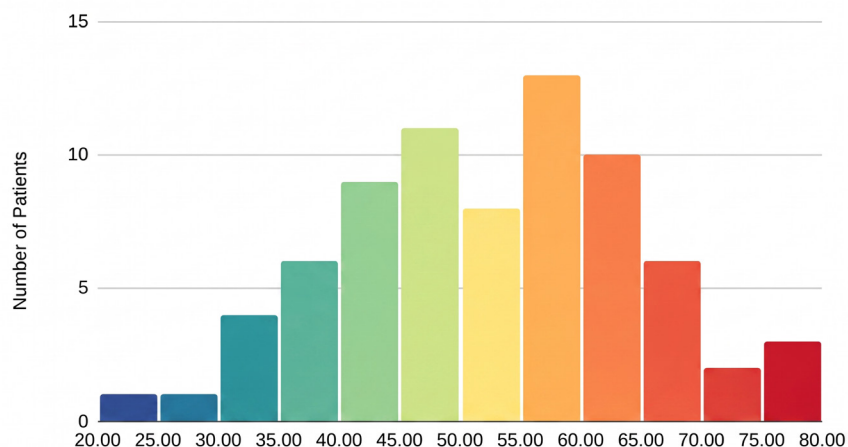


Figure 2. Age distribution of the male population (n = 74)

and 21% male, yielding a 3.9:1 female-to-male ratio. Similarly, unruptured AcomA aneurysms were more frequent in men (29%) than in women (7%), whereas unruptured PcomA aneurysms were more frequent in women (48%) than in men (14%). Due to the small sample size of patients with unruptured aneurysms (n = 34), associations between location and sex were not evaluated. Ninety-three percent of the patients with unruptured PcomA aneurysms were women. Among the patients with unruptured PcomA aneurysms, 71% presented with oculomotor nerve weakness or palsy.

Within the 30-day postoperative period, 22 patients died, for an 8.6% mortality rate. Fifty-four patients experienced a complication, for a 21.2% morbidity rate. Symptomatic cerebral vasospasm occurred in 48 patients (18.8%) and was associated with death in 4 of them; however, the association was not statistically significant. Postoperative weakness was observed in 24 patients (9.4%). Two patients (0.8%) developed some degree of aphasia. Intraoperative rupture occurred in 18 patients (7%) and was associated with death in 2 of them; however, the association was not statistically significant ($P = .6595$). Seven patients (2.7%) developed a postoperative intracranial hemorrhage. In 2 patients with ruptured aneurysms, the aneurysm could not be clipped. One of the patients with a PcomA aneurysm had an intraoperative rupture, and clipping could not be performed during the surgery. The patient had a rebleed the following day and expired. The second patient had a pericallosal aneurysm that caused a large bifrontal intracerebral hemorrhage, and clipping could not be performed due to the

substantial brain swelling and significant cerebral and arterial adhesions near the aneurysm. The patient decided not to have reoperation or embolization and was lost to follow-up 2 years later. Four patients (1.6%) had postoperative rebleeding. Postoperative rebleeding from an unclipped or a partially clipped aneurysm was significantly associated with death in 3 patients ($P < .0021$). An asymptomatic stroke was identified in 14 patients (5.5%). Two patients developed persistent hydrocephalus and were managed with a ventriculoperitoneal shunt. Two patients developed postoperative ptosis that resolved in 3 months. One patient developed ventriculitis that was treated with intravenous antibiotics without the need for ventricular drainage.

Discussion

This study described the surgical experience of a single surgeon over a 25-year period at an academic center, focusing on the management of cerebral aneurysms using open surgical techniques. The entire cohort was Hispanic and living in Puerto Rico; therefore, the findings may be useful for comparison with published reports from other Hispanic countries. There is currently a substantial treatment shift toward endovascular treatment of aneurysms. This shift is attributed to patients' preference for minimally invasive approaches and to some randomized studies demonstrating better one-year functional outcomes with endovascular treatment than with open surgical

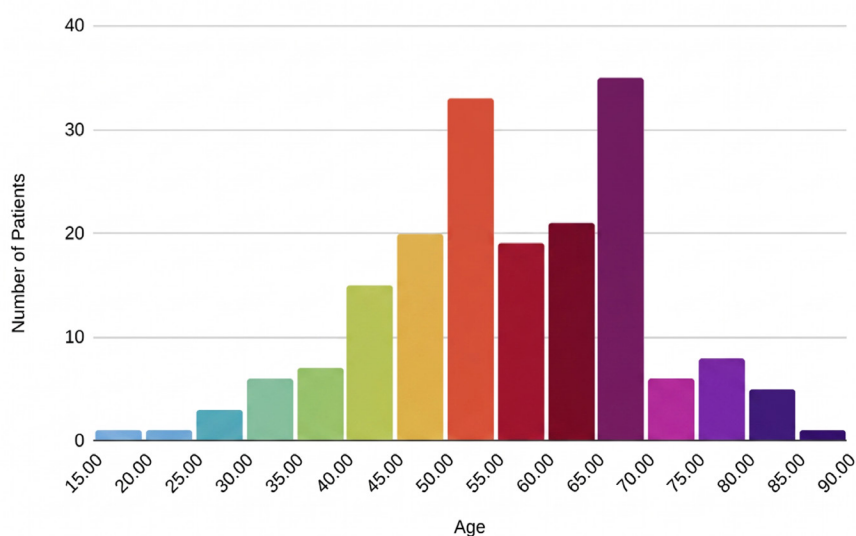
Figure 3. Age distribution of the female population (n = 181)

Table 2. Location of the aneurysms in the entire cohort (n = 255), the ruptured group (n = 221), and the unruptured group (n = 34)

Artery	Entire cohort n (%)	Female cohort n (%)	Male cohort n (%)	Female ruptured n (%)	Male ruptured n (%)	Female unruptured n (%)	Male unruptured n (%)
Anterior communicating	85 (33.3%)	49 (27%)	36 (49%) <i>P</i> < .05	49 (32%)	32 (48%) <i>P</i> = .166	2 (7%)	2 (29%)
Posterior communicating	83 (32.5%)	73 (40%) <i>P</i> < .01	10 (13%)	60 (39%) <i>P</i> < .01	9 (13%)	13 (48%)	1 (14%)
Middle cerebral bifurcation	47 (18.4%)	30 (17%)	17 (23%) <i>P</i> = .387	22 (14%)	14 (21%) <i>P</i> = .335	8 (30%)	3 (43%)
Internal carotid bifurcation	8 (3.1%)	5 (2.8%)	3 (4.1%)	4 (2.6%)	2 (3.0%)	1 (3.7%)	1 (14.2%)
Superior hypophyseal	6 (2.3%)	6 (3.3%)	0 (0%)	4 (2.6%)	0 (0%)	2 (7.4%)	0 (0%)
Pericallosal	5 (2%)	3 (1.7%)	2 (2.7%)	3 (1.9%)	2 (3.0%)	0 (0%)	0 (0%)
Anterior choroidal	5 (2%)	2 (1.1%)	3 (4.1%)	2 (1.3%)	3 (4.5%)	0 (0%)	0 (0%)
Anterior temporal	4 (1.6%)	3 (1.7%)	1 (1.4%)	3 (1.9%)	1 (1.5%)	0 (0%)	0 (0%)
Internal carotid (dorsal wall)	4 (1.6%)	4 (2.2%)	0 (0%)	4 (2.6%)	0 (0%)	0 (0%)	0 (0%)
Posterior inferior cerebellar	3 (1.2%)	3 (1.7%)	0 (0%)	3 (1.9%)	0 (0%)	0 (0%)	0 (0%)
Ophthalmic	2 (0.8%)	1 (0.6%)	1 (1.4%)	1 (0.6%)	1 (1.5%)	0 (0%)	0 (0%)
Anterior inferior cerebellar	1 (0.4%)	0 (0%)	1 (1.4%)	0 (0%)	1 (1.5%)	0 (0%)	0 (0%)
Basilar (tip)	1 (0.4%)	1 (0.6%)	0 (0%)	1 (0.6%)	0 (0%)	0 (0%)	0 (0%)
Cavernous sinus	1 (0.4%)	1 (0.6%)	0 (0%)	0 (0%)	0 (0%)	1 (3.7%)	0 (0%)

P-values were omitted in cells with small counts

treatment (16). However, other studies have shown little or no difference in patient clinical outcomes between clipped and endovascularly treated aneurysms (17-19). Reruptures occur more frequently after endovascular treatment, which should be discussed with the patient and their family during the decision-making process (20). Despite this treatment shift, clipping remains an effective therapy option for patients with ruptured IAs. Because of this treatment shift and the rapid evolution of endovascular techniques for treating IAs, the author noted a slight decrease in surgically treated aneurysms over the last five years of the study.

Sex distribution and age-related patterns

The overall incidence of IAs has been reported to be approximately 1.6-2.8 times higher in females than in males (3,21,22). Flores et al. reported a female-to-male ratio of 2.3:1 for patients with aneurysmal SAH in Puerto Rico (13). The current study's 2.4:1 female-to-male ratio is comparable to that reported in the earlier study. The female predominance in the Hispanic population living in Puerto Rico is higher than that reported in White and Asian populations (3,21). When the current study's data were analyzed by

decade, the female-to-male ratios increased progressively from 2:1 in the third decade to 3.6:1 in the later decades. Similar age-related increases in female-to-male ratios were reported by Hamdan et al., who found ratios of approximately 1.2:1 during the third and fourth decades of life, rising to approximately 1.7:1 in the fifth decade, 2.2:1 in the sixth decade, and 3.5:1 in later decades (23). The authors attributed this finding to reduced estrogen levels with advancing female age, which weakens vascular wall integrity and increases the risk of aneurysm formation (23). Kongable et al. similarly reported increasing female-to-male ratios with advancing age, from 1.5:1 during the second through fourth decades, increasing to 2:1 in the fifth decade, 2.3:1 in the sixth, and 2.7:1 in the later decades (24). In contrast to these two studies, which showed steady female-to-male ratios in the third and fourth decades, the current study found that ratios increased progressively from the third decade onward, reaching a maximum of 3.6:1 after the sixth decade. Consistent with our findings, Peng et al. noted that the peak frequency of aneurysm presentation occurred in the sixth decade in males and the seventh decade in females (21).

Aneurysm distribution

Flores et al. reported that ruptured aneurysms occurred with equal frequency at the AcomA and PcomA (26.4% each), followed by the MCA bifurcation (15.3%) (13). The frequencies of AcomA (33.3%)

and PcomA (32.5%) aneurysms in the current study were comparable to those in the prior report. In the current study, the percentage of MCA aneurysms (18.4%) was slightly higher than in the previous report (15.3%), likely because of the treatment of unruptured mirror-image MCA aneurysms detected after surgery for ruptured MCA aneurysms. The proportion of posterior circulation aneurysms in the current surgical series (2%) was relatively low, as most are now treated endovascularly. The 9.8% frequency of multiple aneurysms observed in this study was slightly lower than the 18.1% reported in the previous study by Flores et al. (13). In studies from China, multiple aneurysms have been reported in 15% to 19% of patients with aneurysmal SAH (21,25). Autopsy studies have reported that 14% to 19% of patients with unruptured aneurysms have multiple aneurysms (26). Female patients have a significantly higher frequency of multiple aneurysms (21,23,24,26,27). Moreover, female patients with ruptured aneurysms are typically older than male patients (22,23,28).

Aneurysm location and sex-related differences

AcomA aneurysms are considered the most prevalent, followed closely by PcomA aneurysms (23,25,28). The current study

Table 3. Similarities and differences with prior literature regarding sex-related incidence, aneurysm location, multiplicity, clinical vasospasm, and mortality.

Reference	Country	F:M ratio	AcomA	PcomA	MCA	Multiple	Vasospasm	Mortality
Kongable et al. 1996 (24)	USA/ Canada	1.77:1	N/R	N/R	17.3%	27.3%	N/R	N/R
Shea et al. 2003 (5)	USA	N/R	N/R	N/R	N/R	N/R	N/R	25.3%
Flores et al. 2020 (13)	Puerto Rico	2.3:1	26.4%	26.4%	15.3%	18.1%	N/R	23.1%
Westphal et al. 2023 (28)	Switzerland	1.74:1	30.9%	45.5%	24.8%	N/R	N/R	N/R
Toader et al. 2024 (39)	Romania	N/R	43.9%	14.7%	27.2%	13.6%	29.2% (R)	24.4%
Peng et al. 2024 (23)	China	1.8:1	N/R	N/R	16.9%	18.9%	N/R	N/R
Current study, 2026	Puerto Rico	2.4:1	33.3%	32.5%	18.4%	9.8%	18.8% (P)	8.6%

Abbreviations: AcomA, anterior communicating artery; F, female; M, male; MCA, middle cerebral artery; N/R, not reported; PcomA, posterior communicating artery; P, postoperative; R, radiologic

corroborates this finding. Several studies of ruptured aneurysms have demonstrated that AcomA aneurysms are significantly more common in men, whereas PcomA aneurysms are more common in women (21-24,28). However, no sex-related difference has been reported for MCA aneurysms (23,24,27-29). The current study results substantiate these sex-related distribution patterns. Lindekleiv et al. reported significantly smaller vessel diameters in female subjects at the ICA bifurcations, resulting in higher blood flow velocity, higher wall shear stress, and greater hemodynamic forces (30). These sex-related hemodynamic differences could explain the higher prevalence of PcomA aneurysms in women. However, their study did not provide measurements of the AcomA to evaluate male dominance at this location. Although sex-related mechanical and hormonal factors may contribute to differences in aneurysm location, the specific mechanisms underlying these differences have yet to be elucidated.

Most studies reporting aneurysm locations use the Koivisto classification (31). In this classification, the anterior cerebral artery (ACA) group includes aneurysms of the anterior communicating artery, the pericallosal artery, and the ACA trunk and perforators. The internal carotid artery (ICA) group includes aneurysms arising from the ophthalmic artery, the posterior communicating artery, the anterior choroidal artery, and the ICA wall and perforators. When the Koivisto classification is used to report aneurysm studies, it is unclear which arterial segments are most frequently involved within the ACA and ICA groups. Studies that have used the Koivisto classification have demonstrated that ruptured ICA aneurysms are significantly more prevalent in women, whereas ACA aneurysms are significantly more prevalent in males (21,23,24,27,32-34). However, Ghods et al. reported that the difference was significant only for ruptured aneurysms at the ACA location (29). Despite sex-related differences in prevalence, progression, and location of

ruptured aneurysms, the overall outcomes among female and male patients are comparable (21-24,27,35).

As with the entire cohort and the ruptured group, in which PcomA aneurysms were more frequent in women, unruptured PcomA aneurysms were also more prevalent in this sex. In the study by Ghods et al., unruptured ICA aneurysms were more prevalent in women, whereas ACA aneurysms were more prevalent in men (29).

Surgical outcomes

In the current study, which included ruptured and unruptured aneurysms, there was an 8.6% mortality rate and a 21.2% morbidity rate. Prior studies have shown that the 30-day mortality after unruptured IA surgery ranges from 0.3% to 2.6%, with approximately 4.1% to 20.7% of patients developing at least one major complication (36-38). Surgical mortality for ruptured aneurysms approaches 25%

(5,39). Up to one-third of the patients with ruptured aneurysms develop symptomatic cerebral vasospasm, which is a significant contributing factor to morbidity and mortality (39,40). Approximately 20% of the patients develop postoperative weakness, which is usually related to vasospasm and delayed cerebral ischemia (41). In the current study, 18.8% of the patients developed postoperative symptomatic cerebral vasospasm; however, this was not associated with mortality. Intraoperative aneurysm rupture and clipping of more than one aneurysm have been associated with an increased risk of postsurgical complications in patients with unruptured anterior circulation aneurysms (41). Furthermore, age over 60 years has been associated with postoperative morbidity in patients with ruptured and unruptured IAs (42).

In the current study, intraoperative rupture occurred in 7% of patients and was not associated with mortality. However, postoperative rebleeding from an unclipped or a partially clipped aneurysm was significantly associated with mortality. Studies of ruptured and unruptured IAs have demonstrated that Hispanic patients have worse outcomes and more complications compared with white patients (43, 44). In addition, Hispanic patients have significantly higher periprocedural cerebral infarction rates (43). Due to this association with worse outcomes and the higher aneurysm prevalence among Hispanics, magnetic resonance angiography has been recommended for Hispanic women as a cost-effective screening tool for unruptured IA detection (6,45). Similarities and differences with prior literature regarding sex-related distribution patterns, aneurysm location, multiplicity, clinical vasospasm, and mortality are summarized in Table 3.

Limitations

This study had several limitations, including its retrospective nature. First, a single surgeon operated on all the patients. Second,

the study did not include all patients with IAs who underwent surgery in Puerto Rico during the study period. Therefore, the true sex-related distribution of aneurysms in Puerto Rico could not be determined. Third, the cohort did not include patients initially evaluated by the author who were treated solely with aneurysm embolization. Thus, the observed distributions by location and sex may have been affected by aneurysms that are more frequently treated endovascularly. Fourth, the sample size of unruptured aneurysms was not sufficient to fully evaluate the associations between location and sex in this critical subgroup. Lastly, this analysis was restricted to the population of Puerto Rico, which may limit the generalizability of the results to other Hispanic populations.

Conclusion

This study found a substantial female predominance among IA patients in Puerto Rico. More than half of the aneurysms occurred in patients aged 50–69 years, suggesting an age-related risk factor. The female-to-male ratio progressively increased from the third decade onward, reaching a maximum of 3.6:1 after the sixth decade. Peak IA presentation occurred in the sixth decade in men and in the seventh decade in women. This cohort of an entirely Hispanic population is consistent with prior literature showing that AcomA aneurysms are more frequent among men, while PcomA aneurysms are more frequent among women. Most patients with unruptured PcomA aneurysms presented with oculomotor nerve weakness or palsy.

Resumen

Objetivo: El objetivo de este estudio fue describir una población hispana en Puerto Rico con aneurismas intracraneales tratados quirúrgicamente por un único cirujano en un centro académico durante 25 años. **Métodos:** Se realizó un estudio retrospectivo utilizando la base de datos electrónica del programa de Neurocirugía de la Universidad de Puerto Rico para identificar a todos los pacientes hispanos con un aneurisma intracraneal que recibieron tratamiento quirúrgico abierto por el autor entre 1996 y 2020. **Resultados:** Durante 25 años, se intervino quirúrgicamente a 255 pacientes con aneurisma intracraneal. Setenta y un por ciento eran mujeres y un 29% eran hombres, con una proporción de 2.4:1 entre mujeres y hombres. La edad mediana de los pacientes fue de 55 años (rango intercuartílico: 46-65 años). El 87% de los pacientes se sometió a cirugía por un aneurisma roto, mientras que el 13% por uno no roto. Las localizaciones más frecuentes de los aneurismas fueron la arteria comunicante anterior (33.3%) y la arteria comunicante posterior (32.5%). Los aneurismas de la arteria comunicante anterior fueron más frecuentes en hombres, mientras que los de la arteria comunicante posterior fueron más frecuentes en mujeres. El resangrado postoperatorio de un aneurisma no grapado o parcialmente grapado se asoció significativamente con la muerte. **Conclusiones:** En el estudio, el sexo femenino predomina sustancialmente entre los pacientes con aneurisma intracraneal. Más de la mitad de los aneurismas tratados se presentaron en pacientes de 50 a 69 años.

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