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Factors associated with intraoperative neuromonitoring changes during temporary clipping in unruptured middle cerebral artery aneurysm surgery: a retrospective cohort study

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Research Article

Keywords: Middle cerebral artery aneurysm, Temporary clipping, Intraoperative neurophysiological monitoring, Motor evoked potentials, Somatosensory evoked potentials, Cerebral ischemia

Posted Date: November 10th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11214700/v1

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Additional Declarations: No competing interests reported.

Abstract

Temporary clipping (TC) facilitates microsurgical dissection of middle cerebral artery (MCA) aneurysms but exposes the downstream territory to transient ischemia, and individual tolerance remains difficult to predict. We retrospectively analyzed 33 patients selected from 140 consecutive patients who underwent intraoperative neuromonitoring (IONM)-assisted microsurgical clipping of unruptured MCA aneurysms between January 2020 and January 2026 and in whom TC was used. Seventy-six TC episodes were classified as IONM(+)TC or IONM(-)TC according to the occurrence of an intraoperative motor- or somatosensory-evoked potential change. IONM changes occurred in 6/33 patients (18.2%). Aneurysms were larger in affected patients (median 11 vs 8 mm; $p = 0.046$). IONM(+)TC episodes were longer than IONM(-)TC episodes (median 262 vs 134 s; $p = 0.021$), whereas IONM(+)TC duration did not differ from maximum tolerated IONM(-)TC duration (262 vs 223 s; $p = 0.363$), and cumulative clipping exposure was similar between groups (314 vs 309 s; $p = 0.657$). All IONM changes recovered after clip release, and no patient developed a new postoperative neurological deficit or radiologically evident ischemic lesion. Longer IONM(+)TC duration was associated with longer recovery time (Pearson $r = 0.93$, $p = 0.007$; Spearman $\rho = 0.94$, $p = 0.005$). These exploratory findings suggest that the duration of an individual uninterrupted TC may be more informative than cumulative exposure, while substantial interindividual variability precludes a universal safe clipping-time threshold.

Introduction

The middle cerebral artery (MCA) is the third most common site of intracranial aneurysms, accounting for approximately 20% of cases, and MCA aneurysms remain among the most common indications for microsurgical clipping [2]. Owing to their frequent location at the MCA bifurcation, complex anatomical relationships with perforators and cortical branches, and the need to preserve distal flow, microsurgical treatment continues to represent the preferred strategy in many cases, particularly for broad-necked, large, or complex aneurysms [16].

Despite advances in microsurgical techniques, ischemic complications remain a major cause of treatment-related morbidity after aneurysm clipping. Intraoperative ischemia may result from prolonged temporary vessel occlusion, inadvertent branch compromise, perforator injury, excessive dome manipulation, or definitive clip malposition [19]. Temporary clipping (TC), a key adjunct for proximal control and safer aneurysm dissection, exposes the brain to transient flow reduction and potential ischemic injury [4]. Tolerance to temporary occlusion is highly variable and may depend on collateral circulation, vascular territory, age, aneurysm complexity, and occlusion duration [8, 13, 15].

Intraoperative neuromonitoring (IONM) can provide real-time functional information during intracranial aneurysm surgery and may identify ischemic compromise while it is still reversible [1, 9–11, 17, 18, 20]. Several studies have specifically investigated IONM changes during TC and have attempted to define permissible occlusion times [5–7, 12, 14]. However, reported temporal thresholds vary considerably, and the relative contribution of the duration of an individual uninterrupted TC episode versus cumulative

clipping exposure, as well as the relationship between TC duration and neurophysiological recovery after reperfusion, remain incompletely characterized.

The aim of the present study was to investigate patient- and temporary clipping-related factors associated with IONM changes during microsurgical clipping of unruptured MCA aneurysms, with particular attention to individual TC duration, cumulative exposure, interindividual tolerance, and IONM recovery after clip release.

Materials and Methods

Study design and patient selection

We retrospectively reviewed 140 consecutive patients who underwent IONM-assisted microsurgical clipping of unruptured MCA aneurysms between January 2020 and January 2026 at our institution and selected patients in whom TC was used during surgery. Eligibility required complete operative reports, neurophysiological monitoring data, and clinical and radiological data. Patients undergoing treatment of multiple aneurysms during the same procedure or lacking complete intraoperative neuromonitoring documentation were excluded. A total of 33 patients were included in the final analysis. Because this retrospective study involved exclusively de-identified data collected during routine clinical care, formal ethics committee approval and individual informed consent were not required according to institutional policy. The study-selection process is summarized in Online Resource 1.

Clinical and radiological data collection

Clinical, surgical, neurophysiological, and radiological data were retrospectively collected from institutional electronic medical records, operative reports, and intraoperative IONM reports. Variables included patient age and sex, aneurysm size, duration of each TC episode, cumulative TC duration, number of TC applications, and IONM changes. Postoperative neurological and radiological outcomes were prespecified from the clinical records and postoperative imaging.

Surgical technique

All procedures were performed by the same cerebrovascular surgical team using standard microsurgical techniques through a minipterional approach [16]. After sylvian fissure dissection, TC was applied when necessary to obtain proximal vascular control, facilitate dome dissection, reduce aneurysm tension, or allow safer definitive clip positioning. The MCA was prepared for proximal TC at the most distal feasible site immediately proximal to the aneurysm neck, with the aim of minimizing compromise of perforating arteries [4, 10, 16, 17, 19].

Intraoperative neurophysiological monitoring

Continuous IONM was performed in all cases using combined motor evoked potentials (MEPs) and somatosensory evoked potentials (SSEPs). MEPs were elicited by transcranial electrical stimulation and

recorded from contralateral upper- and lower-limb muscles; SSEPs were elicited by median and posterior tibial nerve stimulation and continuously recorded throughout surgery [13].

An IONM alert was defined as a > 50% reduction in MEP and/or SSEP amplitude and/or, for SSEPs, a > 10% increase in latency, according to the institutional monitoring protocol [3]. Any significant neurophysiological deterioration was immediately communicated to the surgical team. IONM recovery time was defined as the interval between temporary clip release and recovery of the altered MEP/SSEP signal to its baseline.

Statistical analysis

Continuous variables are presented as mean ± standard deviation or median with interquartile range (IQR), as appropriate, whereas categorical variables are reported as counts and percentages. Normality was assessed using the Shapiro-Wilk test.

Patient-based analyses compared patients with stable IONM with those who developed an intraoperative IONM change. Continuous variables were primarily analyzed using two-sided Mann-Whitney U tests, with Welch's t-tests and permutation tests used as sensitivity analyses; categorical variables were compared using Fisher's exact test. Effect sizes were assessed using rank-biserial correlation and Cohen's d.

For temporary-clipping episode analyses, each TC episode was classified as IONM(+)TC or IONM(-)TC according to whether an intraoperative MEP/SSEP change occurred. IONM(+)TC duration was compared with all IONM(-)TC episodes and with the maximum tolerated IONM(-)TC duration in patients with stable IONM. Cumulative TC exposure was also compared between patients with stable IONM and affected patients up to and including the IONM(+)TC. Two-sided Mann-Whitney U tests were used for these comparisons, with effect-size estimates and Welch's t-tests as supportive analyses. Because some patients contributed multiple TC episodes, temporary-clipping episode analyses were considered exploratory.

Among patients who developed an IONM change, the association between IONM(+)TC duration and IONM recovery time was assessed using Pearson and Spearman correlation coefficients. Kendall correlation, linear regression, permutation testing, bootstrap confidence intervals, and leave-one-out analyses were used as sensitivity analyses.

All tests were two-sided, with $p < 0.05$ considered statistically significant. No adjustment for multiple comparisons was applied because of the small sample size and exploratory nature of the analyses. Statistical analyses were performed using Python 3.13. Figures were generated from the original dataset using R version 4.6.1 (R Foundation for Statistical Computing, Vienna, Austria) with ggplot2.

Results

Study population

Thirty-three patients were included in the final analysis. Mean age was 60.5 ± 12.3 years and median age was 62 years (IQR 52-69). Twenty-seven patients were female (81.8%). Mean aneurysm size was 8.4 ± 3.4 mm, with a median of 9 mm (IQR 6-11).

A total of 76 TCs were performed, corresponding to a mean of 2.3 ± 1.2 TCs per patient and a median of 2 (IQR 1-3). Mean cumulative TC duration was 396 ± 282 s, with a median of 315 s (IQR 227-486). Mean maximum single-TC duration was 243 ± 125 s. An intraoperative IONM change occurred in 6 of 33 patients (18.2%). Six clipping episodes were therefore classified as IONM(+)TC and 70 as IONM(-)TC.

Among the six affected patients, mean IONM(+)TC duration was 251 ± 71 s, with a median of 262 s (IQR 234-287) and a range of 126-336 s. The IONM(+)TC occurred during the first TC in cases 2, 4, 18, and 28 and during the second TC in cases 27 and 33.

Postoperative clinical and radiological outcomes were favorable. No patient developed a new postoperative neurological deficit, and no postoperative ischemic lesions were identified on CT or MRI.

Patient-related factors associated with IONM changes

Results are summarized in Table 1 and Fig. 1. Aneurysms were significantly larger in patients who developed an IONM change than in those with stable IONM (median 11 mm [IQR 9-14.5] vs 8 mm [IQR 5-10]; Mann-Whitney p=0.046). The magnitude of the difference was substantial (Cohen's d=1.28; rank-biserial correlation=0.53), and permutation testing supported the association (p=0.010).

Patients with an IONM change were approximately 9.5 years older on average than patients with stable IONM. However, age did not reach statistical significance in the primary Mann-Whitney analysis (p=0.093) or permutation testing (p=0.081), despite a significant Welch's t-test (p=0.032); therefore, the association between age and IONM changes was not considered robust.

No significant differences were identified in the number of TCs (p=0.343), first-TC duration (p=0.575), maximum single-TC duration (p=0.234), or cumulative TC duration (p=0.263). Excluding case 3, which had a cumulative clipping duration of 1,560 s, did not materially change the cumulative-duration comparison (p=0.192). Sex was not associated with IONM change (p=0.295).

Temporary clipping-related factors associated with IONM changes

Data are summarized in Table 2 and Fig. 2. IONM(+)TC episodes were longer than IONM(-)TC episodes overall. Mean duration was 251 ± 71 s versus 165 ± 118 s, and median duration was 262 s (IQR 234-287) versus 134 s (IQR 87-223), respectively (Mann-Whitney p=0.021). The magnitude of the association was moderate-to-large (Cohen's d=0.74; rank-biserial correlation=0.57). Because some patients contributed multiple clipping episodes, this comparison was considered exploratory.

In contrast, IONM(+)TC duration did not differ significantly from the maximum tolerated IONM(-)TC duration (median 262 vs 223 s; p=0.363). Considerable overlap was observed between the two

distributions: 8 of 27 patients with stable IONM tolerated a maximum TC longer than the median IONM(+)TC duration. This finding indicates substantial interindividual variability in tolerance to temporary occlusion.

Similarly, cumulative clipping exposure did not differ significantly between patients with stable IONM and affected patients up to and including the IONM(+)TC. Median cumulative durations were 309 s (IQR 223-467) and 314 s (IQR 278-337), respectively (p=0.657).

Taken together, these exploratory comparisons suggest that the duration of an individual uninterrupted TC may be more closely associated with IONM change than overall cumulative clipping exposure. However, the substantial overlap between maximum tolerated IONM(-)TC and IONM(+)TC durations indicates marked interindividual variability and does not support identification of a universal temporal threshold.

IONM recovery

IONM signals recovered after clip release in all six affected patients. Mean IONM recovery time was 219 ± 102 s and median recovery time was 215 s (IQR 180-297), with a range of 58-335 s. IONM(+)TC duration showed a strong positive association with IONM recovery time (Pearson r=0.93, p=0.007; Spearman ρ=0.94, p=0.005). Sensitivity analyses were concordant: Kendall τ was 0.87 (p=0.017), the permutation test yielded p=0.008, and the bootstrap 95% CI for Pearson r was 0.52-1.00. Pearson r also remained strongly positive in all leave-one-out analyses (range 0.82-0.99). Linear regression estimated an increase of 1.33 s in IONM recovery time for each additional second of IONM(+)TC duration (95% CI 0.60-2.06; p=0.007). All IONM changes were reversible after temporary clip release, and none of the affected patients developed a new postoperative neurological deficit or radiologically evident ischemic lesion. Given the six observations available, this association should be regarded as exploratory (Fig. 3).

Discussion

The present study investigated patient- and temporary clipping-related factors associated with intraoperative IONM changes during temporary clipping in MCA aneurysm surgery. Our main findings were: (1) aneurysm size was associated with IONM deterioration, whereas age showed only a non-significant trend; (2) IONM(+)TC episodes were longer than IONM(-)TC episodes overall, whereas neither maximum tolerated clipping duration nor cumulative clipping exposure clearly distinguished patients who developed an IONM change; and (3) longer IONM(+)TC duration was strongly associated with longer IONM recovery time after clip release. Taken together, these data suggest that the duration of an individual uninterrupted arterial occlusion may be more relevant to transient neurophysiological deterioration than cumulative TC duration during the procedure.

Regarding patient-related factors, aneurysm size was the only variable significantly associated with IONM change. Patients who developed an IONM change had larger aneurysms than those with stable monitoring. This finding is clinically plausible because larger aneurysms may be associated with greater

anatomical and microsurgical complexity, including more extensive dissection, manipulation of the parent artery and branches, involvement of perforators, and a greater need for temporary proximal control or complex clip reconstruction. Aneurysm size may therefore represent not only a morphological characteristic but also a surrogate marker of the complexity of the vascular environment in which temporary clipping is performed. Nevertheless, the present data establish an association rather than an independent causal effect, particularly because the limited number of IONM events precluded reliable multivariable adjustment. Komatsu et al. [7], in a mixed aneurysm cohort in which TC was used in only nine patients, found no significant difference in aneurysm size between patients with and without MEP deterioration.

Age also showed a potentially relevant signal. Patients with an IONM change were approximately 9.5 years older on average, but the difference did not reach significance with the primary Mann-Whitney analysis or permutation testing. Accordingly, age should not be considered an established predictor on the basis of the present cohort. The direction of the effect remains of potential interest, however, because reduced cerebrovascular reserve and age-related vascular changes could theoretically decrease tolerance to temporary arterial occlusion. Confirmation in a larger cohort would be required before age could be incorporated into risk stratification.

Regarding temporary clipping-related factors, IONM(+)TC episodes were significantly longer than IONM(-)TC episodes overall. This finding supports an association between the duration of an individual uninterrupted TC and transient neurophysiological deterioration. Schick et al. [12] studied aneurysms in multiple vascular territories and reported significantly longer TCs in patients with intraoperative SSEP changes and in those who subsequently developed new neurological deficits. Similarly, Staarmann et al. [14] found longer TC durations in cases with IONM changes and reported mean times to electrophysiological deterioration of approximately 180 s for SSEPs and 258 s for MEPs in MCA aneurysms. Kameda et al. [6], in a cohort of MCA aneurysms, observed severe MEP reduction approximately 348 s after TC application; logistic regression indicated a higher probability of severe MEP deterioration when occlusion lasted 312 s or longer, whereas ROC analysis identified 251 s as the optimal cutoff for detecting severe MEP reduction. Interestingly, the median IONM(+)TC duration in our cohort was 262 s, close to the ROC-derived value reported by Kameda et al. This numerical similarity should not, however, be interpreted as confirmation of a universal temporal threshold. Our data showed substantial overlap between IONM(-)TC and IONM(+)TC durations, and several patients with stable IONM tolerated uninterrupted TCs longer than the median duration of the IONM(+)TC episodes.

The wide range of temporal thresholds reported in the literature further supports a patient-specific interpretation of temporary-occlusion tolerance. Schick et al. [12] concluded that no genuinely safe permissible occlusion time could be defined, whereas Doron et al. [5] reported substantially longer tolerated occlusion times in selected complex anterior-circulation aneurysms managed with direct cortical MEP-guided clipping. These apparently divergent findings likely reflect differences in vascular territory, collateral circulation, temporary-clip position, monitoring technique and frequency,

hemodynamic conditions, and surgical strategy. They are consistent with the substantial overlap between maximum tolerated IONM(-)TC and IONM(+)TC durations observed in our cohort.

Another relevant finding was the absence of a significant association between cumulative TC exposure and IONM change, in contrast with the difference observed when comparing individual IONM(+)TC and IONM(-)TC durations. This suggests that a single prolonged uninterrupted occlusion may have a different physiological impact from a similar total ischemic exposure divided into several shorter episodes. This interpretation is supported by Kameda et al. [6], who found that overall TC duration did not predict either MEP changes or postoperative weakness despite an association between individual TC duration and severe MEP reduction. Our observation should not be interpreted as demonstrating that cumulative ischemic exposure is irrelevant. The duration and adequacy of reperfusion intervals were not systematically quantified, and equal cumulative occlusion times may have different physiological consequences depending on collateral flow, systemic hemodynamics, tissue metabolic reserve, and the extent of reperfusion between successive episodes.

The analysis of neurophysiological recovery provides further support for a duration-dependent effect. All patients who developed IONM changes showed recovery after release of the temporary clip, and longer IONM(+)TC duration was associated with a longer recovery time. Komatsu et al. [7] reported a mean interval from clip release to MEP recovery of 11.0 ± 8.0 minutes and observed a positive but weak and non-significant correlation between occlusion time and MEP recovery time (Spearman $\rho = 0.367$, $p = 0.418$). The stronger association observed in our cohort may partly reflect restriction to MCA aneurysms and reduced anatomical heterogeneity, although this explanation remains speculative. However, both studies support the concept that the consequences of temporary ischemia extend beyond the moment of temporary clip release. Importantly, all IONM changes in our cohort were reversible, and no patient developed a new postoperative neurological deficit or radiologically evident ischemic lesion. This suggests that the observed IONM alterations represented transient functional compromise rather than established ischemic injury.

Our findings highlight the role of IONM as an active component of intraoperative decision-making rather than merely a diagnostic adjunct. In our cohort, neurophysiological deterioration prompted immediate modification of the surgical strategy, including release of the temporary clip and interruption or adjustment of ongoing microsurgical maneuvers, and neurophysiological signals subsequently recovered. Continuous IONM therefore provides patient-specific functional feedback that may be more informative than reliance on predefined temporal limits alone. A neurophysiological alert may identify the point at which an individual patient is approaching the limit of tolerance to temporary arterial occlusion, allowing reperfusion to be restored before functional impairment becomes irreversible.

Limitations

Several limitations should be acknowledged. The retrospective design, small sample size, and limited number of neurophysiological events reduced statistical power and precluded reliable multivariable analysis. The association between aneurysm size and IONM changes should therefore be interpreted as

associative rather than causal, particularly because larger aneurysms may also represent greater surgical complexity and be more likely to require temporary clipping. The comparison including all IONM(-)TC episodes was additionally affected by repeated observations within the same patients, so residual within-patient dependence cannot be excluded. Given the exploratory nature of the study, no adjustment for multiple comparisons was applied, increasing the risk of type I error. Changes in MEPs/SSEPs represent surrogate markers of transient functional impairment rather than direct evidence of irreversible ischemic injury. Furthermore, important determinants of ischemic tolerance, including collateral circulation, cerebrovascular reserve, precise temporary-clip position, systemic hemodynamics, and reperfusion between clipping episodes, were not directly assessed. Finally, because the study was restricted to unruptured MCA aneurysms, its findings may not be generalizable to other vascular territories or ruptured aneurysms.

Conclusions

In this exploratory cohort of patients undergoing microsurgical clipping of unruptured MCA aneurysms, larger aneurysm size was associated with intraoperative IONM deterioration. IONM(+)TC episodes were longer than IONM(-)TC episodes overall. However, the substantial overlap between IONM(+)TC and maximum tolerated IONM(-)TC durations, together with the absence of a significant difference in cumulative clipping exposure, indicates marked interindividual variability and does not support definition of a universal safe clipping-time threshold. Among affected patients, longer IONM(+)TC duration was also associated with longer neurophysiological recovery time after clip release.

Overall, our findings support minimizing the duration of each uninterrupted TC and using continuous IONM to tailor TC duration to individual neurophysiological tolerance. Given the small number of IONM events, repeated temporary-clipping episode observations, and absence of adjustment for multiple comparisons, these results should be regarded as hypothesis-generating and require validation in larger prospective cohorts incorporating reperfusion intervals, vascular anatomy, collateral circulation, hemodynamic variables, and postoperative neurological and radiological outcomes.

Statements and Declarations

Acknowledgements

None

Funding

Authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Clinical Trial Number: not applicable

Conflict of Interests

The authors have no relevant financial or non-financial interests to disclose

Funding

Authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Competing interests

The authors have no relevant financial or non-financial interests to disclose

Author contributions

Conceptualization: AA, VS, RDB, CLS; Methodology: VS; FMC; Data curation: VS, FMC, MDD; Formal analysis: VS; Writing - original draft: VS, FMC; Writing - review and editing: all Authors; Supervision: AA, EM, GS, CLS, GLR. All authors read and approved the final manuscript. VS and FM contributed to this work and share first authorship

Ethics approval

Because this retrospective study analyzed de-identified data derived from routine clinical care, formal ethics committee approval and individual informed consent were not required according to institutional policy and applicable regulations. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Consent to participate

Individual informed consent was not required because the study was retrospective and exclusively involved fully de-identified routinely collected clinical data, in accordance with institutional policy and applicable regulations.

Consent to publish

Not applicable. No identifiable patient information is included in the manuscript.

Use of artificial intelligence

During manuscript preparation, the authors used ChatGPT (OpenAI) and Julius AI (Julius AI Inc.) to assist with language editing, manuscript organization, statistical workflow development, and refinement of the presentation of statistical results. ChatGPT was also used to assist with R code for data visualization. All AI-assisted outputs, code, statistical results, and figures were critically reviewed and verified by the authors against the original data. The authors retain full responsibility for the final manuscript.

Data availability

The datasets are available from the corresponding author on reasonable request.

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Tables

Table 1. Patient characteristics according to intraoperative IONM outcome.

Variable	Overall (n=33)	Stable IONM (n=27)	IONM change (n=6)	P value	Effect size
Aneurysm size, mm	8.4 ± 3.4; 9.0 [6.0-11.0]	7.7 ± 2.8; 8.0 [5.0-10.0]	11.7 ± 4.5; 11.0 [9.0-14.5]	0.046	d=1.28; r_rb=0.53
Age, years	60.5 ± 12.3; 62.0 [52.0-69.0]	58.8 ± 12.5; 61.0 [49.5-69.0]	68.3 ± 7.6; 68.5 [65.8-72.8]	0.093	d=0.80; r_rb=0.45
Female sex, n (%)	27 (81.8)	23 (85.2)	4 (66.7)	0.295	-
Number of temporary clippings	2.3 ± 1.2; 2.0 [1.0-3.0]	2.2 ± 1.2; 2.0 [1.0-3.0]	2.7 ± 1.2; 2.5 [2.0-3.8]	0.343	d=0.38; r_rb=0.25
First-clipping duration, s	178.6 ± 99.3; 150.0 [110.0-241.0]	172.7 ± 98.7; 150.0 [107.0-223.0]	205.2 ± 106.7; 199.5 [120.0-286.5]	0.575	d=0.32; r_rb=0.15
Maximum single-clipping duration, s	243.0 ± 125.1; 229.0 [140.0-289.0]	228.0 ± 108.6; 223.0 [139.5-285.0]	310.5 ± 179.4; 261.5 [234.2-320.2]	0.234	d=0.67; r_rb=0.32
Cumulative clipping duration, s	396.1 ± 281.6; 315.0 [227.0-486.0]	378.3 ± 288.6; 309.0 [223.0-466.5]	476.2 ± 255.1; 443.5 [308.0-516.0]	0.263	d=0.35; r_rb=0.30

Values are mean ± standard deviation; median [interquartile range], unless otherwise indicated. P values are from two-sided Mann-Whitney U tests for continuous variables and two-sided Fisher exact tests for categorical variables. Positive effect sizes indicate higher values in the IONM change group. d, Cohen's d; r_rb, rank-biserial correlation.

Table 2. Exploratory comparisons of temporary clipping duration according to intraoperative IONM outcome.

Contrast	Reference group	Comparison group	Mann-Whitney P	Effect estimate	Interpretation
IONM(+)TC vs all IONM(-)TC	All IONM(-)TC: n=70; 165.2 ± 117.9 s; 134.0 [87.2-223.0]	IONM(+)TC: n=6; 250.8 ± 71.3 s; 261.5 [234.2-286.5]	0.021	d=0.74; r_rb=0.57	IONM(+)TC episodes were longer; repeated observations within patients; exploratory
IONM(+)TC vs maximum tolerated IONM(-)TC	Maximum tolerated IONM(-)TC: n=27; 228.0 ± 108.6 s; 223.0 [139.5-285.0]	IONM(+)TC: n=6; 250.8 ± 71.3 s; 261.5 [234.2-286.5]	0.363	d=0.22; r_rb=0.25	No significant difference; substantial overlap between tolerated and IONM(+)TC durations
Cumulative TC exposure: stable IONM vs IONM change	Stable IONM: total IONM(-)TC, n=27; 378.3 ± 288.6 s; 309.0 [223.0-466.5]	Affected patients: cumulative TC to and including IONM(+)TC, n=6; 285.0 ± 83.2 s; 313.5 [277.5-336.8]	0.657	d=-0.35; r_rb=-0.12	No significant difference; cumulative clipping exposure was not discriminatory

Values are mean ± standard deviation; median [interquartile range]. P values are from two-sided Mann-Whitney U tests. Effect estimates are expressed as Cohen's d and rank-biserial correlation (r_rb).

Figures

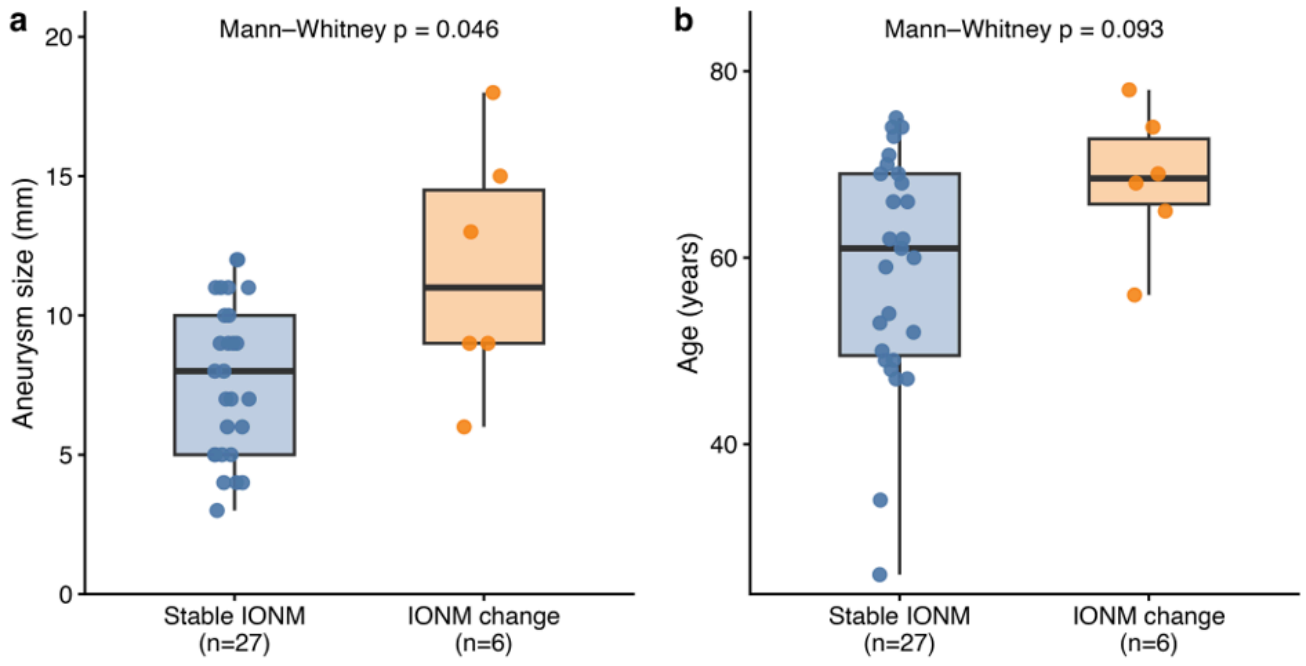


Figure 1

Comparison of aneurysm size and age according to intraoperative IONM outcome. (a) Aneurysm size and (b) age in patients with stable IONM and in those with an intraoperative IONM change. Boxes indicate the interquartile range, horizontal lines the median, and points individual patients. P values are from two-sided Mann-Whitney U tests

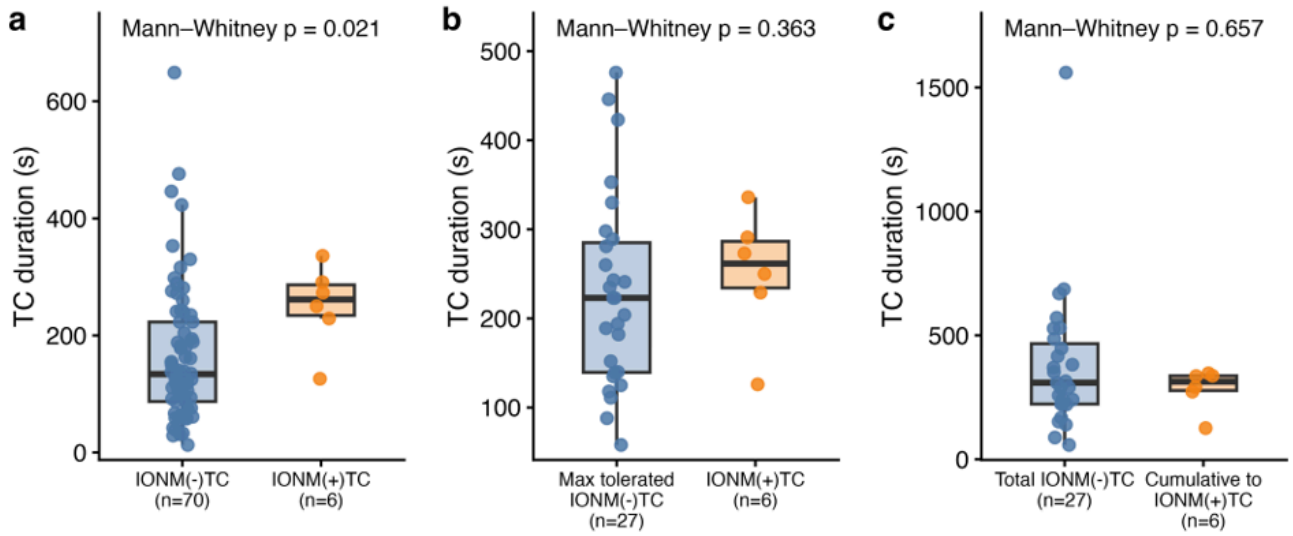


Figure 2

Exploratory temporary-clipping duration comparisons according to intraoperative IONM outcome. (a) Duration of all IONM(-)TC episodes versus IONM(+)TC episodes. (b) Maximum single IONM(-)TC duration in patients with stable IONM versus IONM(+)TC duration. (c) Total cumulative IONM(-)TC duration in patients with stable IONM versus cumulative TC duration up to and including the IONM(+)TC in affected patients. Boxes represent the interquartile range, horizontal lines the median, and points individual observations. p values are from two-sided Mann-Whitney U tests

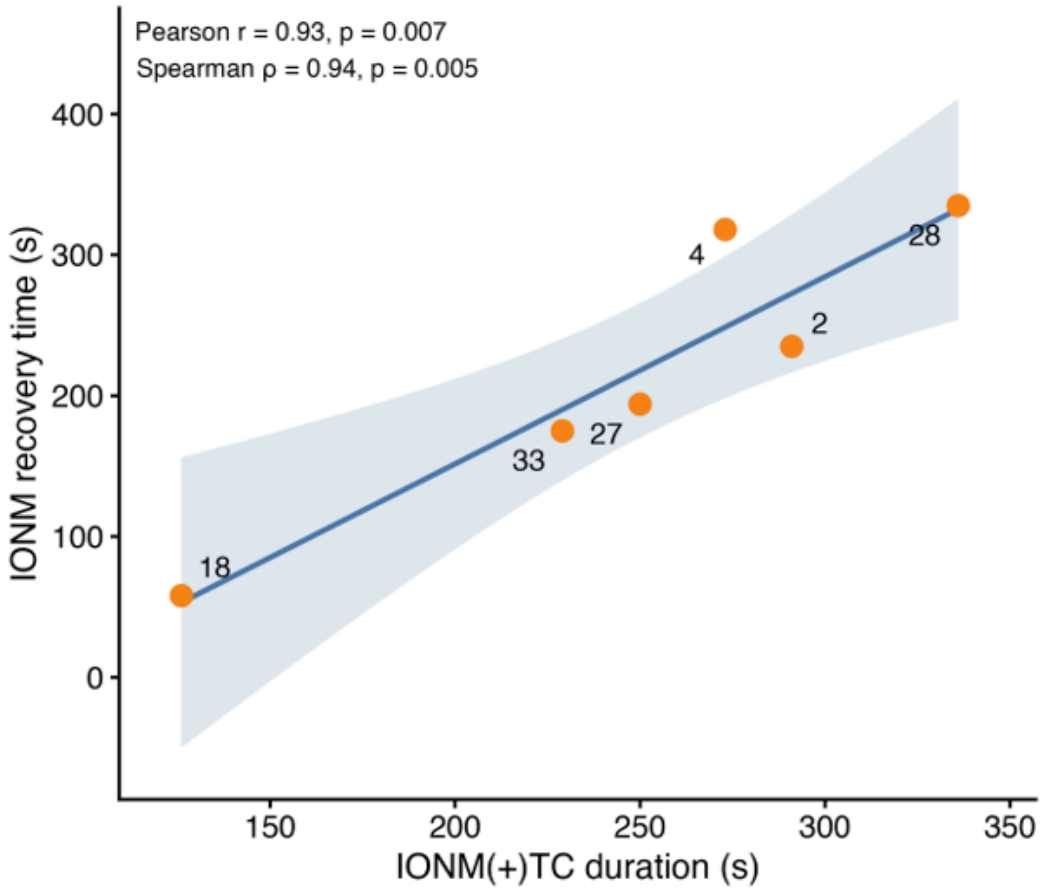


Figure 3

Association between IONM(+)TC duration and IONM recovery time in the six affected patients. Points are labelled by case number. The solid line represents the ordinary least-squares regression line and the shaded region the 95% confidence interval for the mean fitted response. Pearson and Spearman correlation coefficients are reported in the figure

Supplementary Files

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- OnlineResource1.png