Recuperación neuromuscular evaluada mediante Train-Of-Four en cirugía estética bajo anestesia general con rocuronio frente a cisatracurium en la detección de relajación residual

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RESUMEN

La relajación neuromuscular residual continúa siendo una complicación relevante en anestesia general, especialmente en cirugía estética, donde los procedimientos prolongados y el sobrepeso aumentan el riesgo de eventos respiratorios postoperatorios. Aunque rocuronio y cisatracurium son los bloqueadores neuromusculares más utilizados, la evidencia comparativa sobre su recuperación medida mediante Train-of-Four (TOF) en población estética latinoamericana es limitada.

Objetivo: Comparar la recuperación neuromuscular evaluada mediante Train-of-Four en pacientes sometidas a cirugía estética bajo anestesia general con rocuronio frente a cisatracurium, determinando la incidencia de relajación neuromuscular residual (TOF < 0.9) y los factores clínicos y anestésicos asociados en el postoperatorio inmediato.

Metodología: Se realizó un estudio analítico comparativo, observacional y prospectivo. Se incluyeron pacientes ≥18 años sometidas a procedimientos estéticos electivos (liposucción, pexia mamaria, dermolipectomía) con uso exclusivo de rocuronio o cisatracurium y monitoreo cuantitativo estandarizado mediante aceleromiografía. Se registraron valores de TOF en tiempos definidos (30, 60, 90, 120 min y al egreso), además de datos clínicos y quirúrgicos. Se evaluaron características basales, evolución del TOF y presencia de relajación residual. Las comparaciones se realizaron mediante t de Student/Wilcoxon y Chi-cuadrado/Fisher. Se aplicó regresión logística multivariada para identificar factores asociados a TOF < 0.9 al egreso.

Resultados: La muestra presentó media de edad de 35 ± 8.2 años y un IMC promedio de 26.6 ± 2.9 kg/m², con sobrepeso/obesidad en el 57 %. No hubo diferencias significativas entre los grupos en edad, IMC, comorbilidades ni tipo de procedimiento. La recuperación del TOF mostró diferencias iniciales leves entre rocuronio y cisatracurium (p. ej., TOF a 30 min: 0.12 vs. 0.04), pero valores comparables a partir de los 90 minutos (0.82 vs. 0.79). La incidencia global de relajación neuromuscular residual fue del 17 %. En el análisis multivariado, el uso de rocuronio se asoció con mayor probabilidad de TOF < 0.9 (OR 2.59; IC95% 1.95–9.56), mientras que el sobrepeso/obesidad también mostró asociación significativa (OR 1.35; IC95% 1.25–4.79). La duración quirúrgica y la ausencia de monitoreo continuo se relacionaron con mayor variabilidad en la recuperación.

Conclusión: En cirugía estética, el uso de rocuronio y el sobrepeso incrementan el riesgo de relajación residual, incluso bajo monitoreo cuantitativo. Los hallazgos respaldan la implementación sistemática de TOF, el ajuste de dosis por IMC y estrategias de reversión más rigurosas en protocolos anestésicos del Caribe colombiano.

Palabras clave: relajación neuromuscular residual; Train-of-Four; rocuronio; cisatracurium; cirugía estética; monitoreo neuromuscular; anestesia general.

ABSTRACT

Residual neuromuscular blockade remains a relevant complication in general anesthesia, particularly in aesthetic surgery, where prolonged procedures and overweight increase the risk of postoperative respiratory events. Although rocuronium and cisatracurium are the most widely used neuromuscular blockers, comparative evidence on their recovery profiles measured by Train-of-Four (TOF) in Latin American aesthetic surgery populations is limited.

Objective: To compare neuromuscular recovery assessed by Train-of-Four in patients undergoing aesthetic surgery under general anesthesia with rocuronium versus cisatracurium, determining the incidence of residual neuromuscular blockade (TOF < 0.9) and the associated clinical and anesthetic factors in the immediate postoperative period.

Methods: A prospective, observational, comparative analytical study was conducted. Patients ≥18 years undergoing elective aesthetic procedures (liposuction, mastopexy, abdominoplasty) with exclusive use of either rocuronium or cisatracurium and standardized quantitative monitoring via acceleromyography were included. TOF values were recorded at defined intervals (30, 60, 90, 120 minutes and at discharge), along with clinical and surgical variables. Baseline characteristics, TOF progression, and presence of residual blockade were analyzed. Comparisons were performed using Student's t/Wilcoxon tests and Chi-square/Fisher tests. A multivariate logistic regression was applied to identify factors associated with TOF < 0.9 at discharge.

Results: The sample showed a mean age of 35 ± 8.2 years and an average BMI of 26.6 ± 2.9 kg/m², with overweight/obesity present in 57%. No significant differences between groups were found in age, BMI, comorbidities, or procedure type. TOF recovery showed mild early differences between rocuronium and cisatracurium (e.g., TOF at 30 min: 0.12 vs. 0.04), but values became comparable after 90 minutes (0.82 vs. 0.79). The overall incidence of residual blockade was 17%. In the multivariate analysis, rocuronium use was associated with a higher likelihood of TOF < 0.9 (OR 2.59; 95%CI 1.95–9.56), while overweight/obesity also showed a significant association (OR 1.35; 95%CI 1.25–4.79). Longer surgical duration and lack of continuous monitoring were associated with greater variability in recovery.

Conclusion: In aesthetic surgery, rocuronium use and overweight increase the risk of residual neuromuscular blockade, even under quantitative monitoring. These findings support the systematic implementation of TOF monitoring, BMI-adjusted dosing, and more rigorous reversal strategies in anesthetic protocols in the Colombian Caribbean.

Keywords: residual neuromuscular blockade; Train-of-Four; rocuronium; cisatracurium; aesthetic surgery; neuromuscular monitoring; general anesthesia.

REFERENCIAS BIBLIOGRÁFICAS

[1] Murphy GS, Brull SJ. Residual neuromuscular block: lessons unlearned. Part I: definitions, incidence, and adverse physiologic effects of residual neuromuscular block. Anesth Analg 2010;111:120–8. https://doi.org/10.1213/ANE.0b013e3181da832d.

[2] Hattori J, Tanaka A, Kosaka J, Hirao O, Furushima N, Maki Y, et al. Clinical predictors of extubation failure in postoperative critically ill patients: a post-hoc analysis of a multicenter prospective observational study. BMC Anesthesiol 2025;25:127. https://doi.org/10.1186/s12871-025-02996-1.

[3] Naguib M, Kopman AF, Lien CA, Hunter JM, Lopez A, Brull SJ. A survey of current management of neuromuscular block in the United States and Europe. Anesth Analg 2010;111:110–9. https://doi.org/10.1213/ANE.0b013e3181c07428.

[4] Fortier L-P, McKeen D, Turner K, de Médicis É, Warriner B, Jones PM, et al. The RECITE Study: A Canadian Prospective, Multicenter Study of the Incidence and Severity of Residual Neuromuscular Blockade. Anesth Analg 2015;121:366–72. https://doi.org/10.1213/ANE.0000000000000757.

[5] Thilen SR, Weigel WA. Neuromuscular Blockade Monitoring. Anesthesiol Clin 2021;39:457–76. https://doi.org/10.1016/j.anclin.2021.05.001.

[6] Donati F. Neuromuscular monitoring: what evidence do we need to be convinced? Anesth Analg 2010;111:6–8. https://doi.org/10.1213/ANE.0b013e3181cdb093.

[7] Robertson EN, Driessen JJ, Vogt M, De Boer H, Scheffer GJ. Pharmacodynamics of rocuronium 0.3 mg kg(-1) in adult patients with and without renal failure. Eur J Anaesthesiol 2005;22:929–32. https://doi.org/10.1017/S0265021505001584.

[8] Farag E, Rivas E, Bravo M, Hussain S, Argalious M, Khanna S, et al. Sugammadex Versus Neostigmine for Reversal of Rocuronium Neuromuscular Block in Patients Having Catheter-Based Neurointerventional Procedures: A Randomized Trial. Anesth Analg 2021;132:1666–76. https://doi.org/10.1213/ANE.0000000000005533.

[9] Mellinghoff H, Diefenbach C. [The clinical pharmacology of cisatracurium]. Anaesthesist 1997;46:481–5. https://doi.org/10.1007/s001010050427.

[10] Lepage JY, Malinovsky JM, Malinge M, Lechevalier T, Dupuch C, Cozian A, et al. Pharmacodynamic dose-response and safety study of cisatracurium (51W89) in adult surgical patients during N2O-O2-opioid anesthesia. Anesth Analg 1996;83:823–9. https://doi.org/10.1097/00000539-199610000-00030.

[11] Hanley MJ, Abernethy DR, Greenblatt DJ. Effect of obesity on the pharmacokinetics of drugs in humans. Clin Pharmacokinet 2010;49:71–87. https://doi.org/10.2165/11318100-000000000-00000.

[12] Ariza F, Dorado F, Enríquez LE, González V, Gómez JM, Chaparro-Mendoza K, et al. Postoperative residual curarization at the post-anesthetic care unit of a university hospital: A cross-sectional study. Colomb J Anesthesiol 2017;45:15–21. https://doi.org/10.1016/j.rcae.2016.11.002.

[13] Davis LA, Fogarty MJ, Brown A, Sieck GC. Structure and Function of the Mammalian Neuromuscular Junction. Compr Physiol 2022;12:3731–66. https://doi.org/10.1002/cphy.c210022.
[14] Unwin N. Nicotinic acetylcholine receptor and the structural basis of neuromuscular transmission: insights from Torpedo postsynaptic membranes. Q Rev Biophys 2013;46:283–322. https://doi.org/10.1017/S0033583513000061.
[15] Tintignac LA, Brenner H-R, Rüegg MA. Mechanisms Regulating Neuromuscular Junction Development and Function and Causes of Muscle Wasting. Physiol Rev 2015;95:809–52. https://doi.org/10.1152/physrev.00033.2014.
[16] Naguib M, Brull SJ, Johnson KB. Conceptual and technical insights into the basis of neuromuscular monitoring. Anaesthesia 2017;72 Suppl 1:16–37. https://doi.org/10.1111/anae.13738.
[17] Duţu M, Ivaşcu R, Tudorache O, Morlova D, Stanca A, Negoiţă S, et al. Neuromuscular monitoring: an update. Rom J Anaesth Intensive Care 2018;25:55–60. https://doi.org/10.21454/rjaic.7518.251.nrm.
[18] Aragón-Benedí C, Pascual-Bellosta A, Ortega-Lucea S, Visiedo-Sánchez S, Martínez-Ubieto J, Research Group in Anaesthesia, Resuscitation and PM of I for HRA (ISS A. Predictive study of pharmacological reversal for residual neuromuscular blockade and postoperative pulmonary complications: a prospective, observational, cohort study. Sci Rep 2022;12:14955. https://doi.org/10.1038/s41598-022-18917-y.
[19] Bucheery BA, Isa HM, Rafiq O, Almansoori NA, Razaq ZAA, Gawe ZA, et al. Residual Neuromuscular Blockade and Postoperative Pulmonary Complications in the Post-anesthesia Care Unit: A Prospective Observational Study. Cureus 2023. https://doi.org/10.7759/cureus.51013.
[20] Vélez-Agudelo DL, Salazar-Cortés SA, García A, Casas-Arroyave FD. Incidence of postoperative residual neuromuscular blockade: a prospective observational study. Colomb J Anesthesiol 2025;53. https://doi.org/10.5554/22562087.e1146.
[21] Kirmeier E, Eriksson LI, Lewald H, Jonsson Fagerlund M, Hoeft A, Hollmann M, et al. Post-anaesthesia pulmonary complications after use of muscle relaxants (POPULAR): a multicentre, prospective observational study. Lancet Respir Med 2019;7:129–40. https://doi.org/10.1016/S2213-2600(18)30294-7.
[22] Brull SJ, Kopman AF. Current Status of Neuromuscular Reversal and Monitoring: Challenges and Opportunities. Anesthesiology 2017;126:173–90. https://doi.org/10.1097/ALN.0000000000001409.
[23] Cammu G. Residual Neuromuscular Blockade and Postoperative Pulmonary Complications: What Does the Recent Evidence Demonstrate? Curr Anesthesiol Rep 2020;10:131–6. https://doi.org/10.1007/s40140-020-00388-4.
[24] Szewczyk M, Bieniecka A, Sobolewski K, Banasiak Ł, Grabarczyk Ł. Neuromuscular Blocking Agents and Reversal Agents Usage, and Neuromuscular Blockade Monitoring in the Intensive Care Unit - Review

Article. Int J Gen Med 2025;18:3651–88. https://doi.org/10.2147/IJGM.S524089.

[25] Frenkel M, Lien CA. Eliminating residual neuromuscular blockade: a literature review. Ann Transl Med 2024;12:65–65. https://doi.org/10.21037/atm-23-1743.

[26] Blum FE, Locke AR, Nathan N, Katz J, Bissing D, Minhaj M, et al. Residual Neuromuscular Block Remains a Safety Concern for Perioperative Healthcare Professionals: A Comprehensive Review. J Clin Med 2024;13. https://doi.org/10.3390/jcm13030861.

[27] Jung KT, An TH. Updated review of resistance to neuromuscular blocking agents. Anesth Pain Med 2018;13:122–7. https://doi.org/10.17085/apm.2018.13.2.122.

[28] Feltracco P, Tonetti T, Barbieri S, Frigo AC, Ori C. Cisatracurium- and rocuronium-associated residual neuromuscular dysfunction under intraoperative neuromuscular monitoring and postoperative neostigmine reversal: a single-blind randomized trial. J Clin Anesth 2016;35:198–204. https://doi.org/10.1016/j.jclinane.2016.07.031.

[29] Erstad BL, Barletta JF. Dosing of neuromuscular blocking agents in patients with obesity: A narrative review. Anaesth Intensive Care 2021;49:98–104. https://doi.org/10.1177/0310057X20968573.

[30] Doo AR, Lee JH, Lee Y, Ko S. Influence of the amount of skeletal muscle mass on rocuronium-induced neuromuscular block. Anaesthesia, Crit Care Pain Med 2022;41:101086. https://doi.org/10.1016/j.accpm.2022.101086.

[31] Hu Z, Li B, Li Z, Liu Z, Liu S. Feasibility of calculating rocuronium dosage by skeletal muscle weight in patients with obesity. Front Med 2024;11. https://doi.org/10.3389/fmed.2024.1399475.

[32] Huang X, Chen L, Cai Y, Wei J, Lin L, Sun J, et al. Abnormal cisatracurium pharmacodynamics and pharmacokinetics among patients with severe aortic regurgitation during anesthetic induction. BMC Anesthesiol 2020;20:21. https://doi.org/10.1186/s12871-020-0935-z.

[33] Khan R, Kaul N, Nair R. Cisatracurium degradation: Intravenous fluid warmer the culprit? Indian J Anaesth 2015;59:323. https://doi.org/10.4103/0019-5049.156893.

[34] Motamed C. Intraoperative Monitoring of Neuromuscular Blockade. Life (Basel, Switzerland) 2023;13. https://doi.org/10.3390/life13051184.

[35] Thilen SR, Weigel WA, Todd MM, Dutton RP, Lien CA, Grant SA, et al. 2023 American Society of Anesthesiologists Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade: A Report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade. Anesthesiology 2023;138:13–41. https://doi.org/10.1097/ALN.0000000000004379.

[36] Bhananker SM, Treggiari MM, Sellers BA, Cain KC, Ramaiah R, Thilen SR. Comparison of train-of-four count by anesthesia providers versus TOF-Watch® SX: a prospective cohort study. Can J Anaesth 2015;62:1089–96. https://doi.org/10.1007/s12630-015-0433-9.

[37] Asztalos L, Boktor M, Kukuly M, Sólyom D, Pongrácz A, Brull SJ, et al. The

Relationship Between Neuromuscular Block Depth and Airway Retroglossal Area: A Prospective, Nonrandomized, Observational Clinical Trial. J Clin Med 2025;14. https://doi.org/10.3390/jcm14124374.

[38] Lee W. The latest trend in neuromuscular monitoring: return of the electromyography. Anesth Pain Med 2021;16:133–7. https://doi.org/10.17085/apm.21014.

[39] Edwards L-A, Ly N, Shinefeld J, Morewood G. Universal quantitative neuromuscular blockade monitoring at an academic medical center, A multimodal analysis of the potential impact on clinical outcomes and total cost of care. Perioper Care Oper Room Manag 2021;24:100184. https://doi.org/10.1016/j.pcorm.2021.100184.

[40] Rodney G, Raju PKBC, Brull SJ. Residual neuromuscular block: time to consign it to history. Anaesthesia 2024;79:344–8. https://doi.org/10.1111/anae.16238.

[41] The American Society of Plastic Surgeons. American Society of Plastic Surgeons. 2023.

[42] International Society of Aesthetic Plastic Surgery (ISAPS). ISAPS INTERNATIONAL SURVEY ON AESTHETIC/COSMETIC PROCEDURES. 2020.

[43] Ellsworth WA, Basu CB, Iverson RE. Perioperative considerations for patient safety during cosmetic surgery - preventing complications. Can J Plast Surg 2009;17:9–16.

[44] Motta FJTRA DA, Luna ICG, Fabiani IM, Souza JCDS, Amorim VEM, Sá JZ DE. Preoperative hypovitaminosis D and complications in plastic surgery: a pilot study. Rev Col Bras Cir 2024;51:e20243719. https://doi.org/10.1590/0100-6991e-20243719-en.

[45] Fischer JP, Wes AM, Serletti JM, Kovach SJ. Complications in body contouring procedures: an analysis of 1797 patients from the 2005 to 2010 American College of Surgeons National Surgical Quality Improvement Program databases. Plast Reconstr Surg 2013;132:1411–20. https://doi.org/10.1097/PRS.0b013e3182a806b3.

[46] Sakızcı-Uyar B, Çelik S, Postacı A, Bayraktar Y, Dikmen B, Özkoçak-Turan I, et al. Comparison of the effect of rocuronium dosing based on corrected or lean body weight on rapid sequence induction and neuromuscular blockade duration in obese female patients. Saudi Med J 2016;37:60–5. https://doi.org/10.15537/smj.2016.1.14099.

[47] Murphy GS, Brull SJ. Quantitative Neuromuscular Monitoring and Postoperative Outcomes: A Narrative Review. Anesthesiology 2022;136:345–61. https://doi.org/10.1097/ALN.0000000000004044.

[48] Bijkerk V, Krijtenburg P, Verweijen T, Bruhn J, Scheffer GJ, Keijzer C, et al. Residual neuromuscular block in the postanaesthesia care unit: a single-centre prospective observational study and systematic review. Br J Anaesth 2025;134:350–7. https://doi.org/10.1016/j.bja.2024.07.043.

[49] Esteves S, Correia de Barros F, Nunes CS, Puga A, Gomes B, Abelha F, et al. Incidence of postoperative residual neuromuscular blockade - A multicenter, observational study in Portugal (INSPIRE 2). Porto Biomed J

2023;8:e225. https://doi.org/10.1097/j.pbj.0000000000000225.
[50] Swanson E. Prospective Outcome Study of 360 Patients Treated with Liposuction, Lipoabdominoplasty, and Abdominoplasty. Plast Reconstr Surg 2012;129:965–78. https://doi.org/10.1097/PRS.0b013e318244237f.
[51] Niu L, Wang Y, Yao C, Sun Y, Yao S, Lin Y. Efficacy and Safety of Neuromuscular Blockade in Overweight Patients Undergoing Nasopharyngeal Surgery. Med Sci Monit 2020;26. https://doi.org/10.12659/MSM.926452.
[52] Lemmens HJ. Perioperative pharmacology in morbid obesity. Curr Opin Anaesthesiol 2010;23:485–91. https://doi.org/10.1097/ACO.0b013e32833b0a8c.
[53] Kim KS, Cheong MA, Lee HJ, Lee JM. Tactile Assessment for the Reversibility of Rocuronium-Induced Neuromuscular Blockade During Propofol or Sevoflurane Anesthesia. Anesth Analg 2004;99:1080–5. https://doi.org/10.1213/01.ANE.0000130616.57678.80.
[54] Blobner M, Eriksson LI, Scholz J, Motsch J, Della Rocca G, Prins ME. Reversal of rocuronium-induced neuromuscular blockade with sugammadex compared with neostigmine during sevoflurane anaesthesia: results of a randomised, controlled trial. Eur J Anaesthesiol 2010;27:874–81. https://doi.org/10.1097/EJA.0b013e32833d56b7.
[55] Plaud B, Debaene B, Donati F, Marty J. Residual Paralysis after Emergence from Anesthesia. Anesthesiology 2010;112:1013–22. https://doi.org/10.1097/ALN.0b013e3181cded07.
[56] Hunter JM. Rocuronium: the newest aminosteroid neuromuscular blocking drug. Br J Anaesth 1996;76:481–3. https://doi.org/10.1093/bja/76.4.481.
[57] Wastila WB, Maehr RB, Turner GL, Hill DA, Phil. M, Savarese JJ. Comparative Pharmacology of Cisatracurium (51W89), Atracurium, and Five Isomers in Cats. Anesthesiology 1996;85:169–77. https://doi.org/10.1097/00000542-199607000-00023.
[58] Lu I-C, Tan H, Wu S-H, Huang T-Y, Tseng H-Y, Wang J-J, et al. A comparison between cisatracurium and rocuronium-induced neuromuscular block on laryngeal electromyography recovery after neostigmine reversal in a porcine model. Front Endocrinol (Lausanne) 2022;13. https://doi.org/10.3389/fendo.2022.875597.
[59] Li G, Freundlich RE, Gupta RK, Hayhurst CJ, Le CH, Martin BJ, et al. Postoperative Pulmonary Complications' Association with Sugammadex versus Neostigmine: A Retrospective Registry Analysis. Anesthesiology 2021;134:862–73. https://doi.org/10.1097/ALN.0000000000003735.
[60] Carron M, Zarantonello F, Tellaroli P, Ori C. Efficacy and safety of sugammadex compared to neostigmine for reversal of neuromuscular blockade: a meta-analysis of randomized controlled trials. J Clin Anesth 2016;35:1–12. https://doi.org/10.1016/j.jclinane.2016.06.018.
[61] Todd MM, Hindman BJ, King BJ. The Implementation of Quantitative Electromyographic Neuromuscular Monitoring in an Academic Anesthesia Department. Anesth Analg 2014;119:323–31. https://doi.org/10.1213/ANE.0000000000000261.

[62] Fuchs-Buder T, Claudius C, Skovgaard LT, Eriksson LI, Mirakhur RK, Viby-Mogensen J. Good clinical research practice in pharmacodynamic studies of neuromuscular blocking agents II: the Stockholm revision. Acta Anaesthesiol Scand 2007;51:789–808. https://doi.org/10.1111/j.1399-6576.2007.01352.x.