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Clinical and Sociodemographic Outcomes in the First 100 Cases of Robot-Assisted Arthroplasty in Colombia: A Cross-Sectional Study

Resultados clínicos y sociodemográficos en los primeros 100 casos de artroplastia asistida por robot en Colombia: estudio transversal

Resultados clínicos e sociodemográficos nos primeiros 100 casos de artroplastia assistida por robô na Colômbia: estudo transversa

Alejandra Mendoza-Monsalve <https://orcid.org/0000-0002-7377-2920>

<https://ror.org/00q67qp92>

mmendoza806@unab.edu.co *Corresponding Author

Fundación Cardiovascular de Colombia. Piedecuesta, Colombia.

Maricel Licht-Ardila <https://orcid.org/0000-0002-1629-9890>

<https://ror.org/00q67qp92>

maricellicht@fcv.org

Fundación Cardiovascular de Colombia. Piedecuesta, Colombia.

Edgar Fabián Manrique-Hernández <https://orcid.org/0000-0002-3634-8821>

<https://ror.org/00q67qp92>

fabianmh1993@gmail.com

Fundación Cardiovascular de Colombia. Piedecuesta, Colombia.

Alexandra Hurtado-Ortiz <https://orcid.org/0000-0002-3001-2374>

<https://ror.org/00q67qp92>

alexandrajhop@gmail.com

Fundación Cardiovascular de Colombia. Piedecuesta, Colombia.

Jose Ferney Mejia-Duarte <https://orcid.org/0009-0009-3287-7222>

<https://ror.org/04m9gzc43>

jfmejiad@unbosque.edu.co

Universidad El Bosque. Bogotá D.C., Colombia.

Elio David Rueda Cadena <https://orcid.org/0009-0008-3914-4219>

<https://ror.org/00q67qp92>

contacto.medico@clinicadelarodilla.com

Fundación Cardiovascular de Colombia. Piedecuesta, Colombia.

Carlos Enrique Osorio-López <https://orcid.org/0009-0003-7022-1116>

<https://ror.org/00q67qp92>

carlososorio@fcv.org

Fundación Cardiovascular de Colombia. Piedecuesta, Colombia.

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Author Contributions

AMM. Conceptualization, methodology, data analysis, original writing. **MLA.** Critical review of the content, data analysis, interpretation of results. **EFMH.** Experimental design,

data collection, manuscript writing. **AHO.** Literature review, data analysis, theoretical framework development. **JFMD.** Statistical analysis, data interpretation, discussion development. **EDRC.** Data analysis, manuscript section writing, final version review. **CEOL.** Research supervision, contribution to data analysis and manuscript writing.

ABSTRACT

Introduction. Robotic orthopedic surgery was introduced in Colombia in late 2023, representing a major technological advancement in joint replacement surgery. This study aimed to describe the sociodemographic characteristics, perioperative variables, and clinical outcomes of the first 100 patients undergoing robot-assisted total hip and knee arthroplasty using the Mako® robotic arm system in a high-complexity institution in Colombia.

Methodology. A cross-sectional study was conducted between December 2023 and July 2024, including the first 100 patients undergoing robot-assisted total hip and knee arthroplasty. Clinical and demographic variables were obtained from electronic medical records. Continuous variables were summarized using descriptive statistics, while categorical variables were reported as frequencies and percentages. **Results.** Among the 100 patients, 69% were women, with a median age of 72 years (IQR 66–78). Most procedures corresponded to primary tricompartmental total knee arthroplasty. Regional anesthesia was administered in 96% of patients, and 94% received postoperative opioids. Hemoglobin levels decreased from 13.2 g/dL to 11.7 g/dL ($p < 0.001$). **Discussion.** The initial implementation of robot-assisted arthroplasty demonstrated favorable perioperative and postoperative outcomes, supporting the feasibility and safety of robotic orthopedic surgery in a middle-income country context. **Conclusions.** Robotic orthopedic surgery showed positive early

clinical outcomes and may contribute to optimizing surgical precision and postoperative recovery in joint replacement procedures.

Keywords: Arthroplasty, Replacement, Knee; Arthroplasty, Replacement, Hip; Robotic Surgical Procedures; Orthopedic Procedures; Knee; Hip; Surgery, Computer-Assisted; Prosthesis Implantation.

RESUMEN

Introducción. La cirugía ortopédica robótica inició en Colombia a finales de 2023, representando un importante avance tecnológico en cirugía de reemplazo articular. El objetivo de este estudio fue describir las características sociodemográficas, variables perioperatorias y desenlaces clínicos de los primeros 100 pacientes sometidos a artroplastia total de cadera y rodilla asistida por el sistema robótico Mako® en una institución de alta complejidad en Colombia. **Metodología.** Se realizó un estudio transversal entre diciembre de 2023 y julio de 2024, incluyendo los primeros 100 pacientes sometidos a artroplastia total de cadera y rodilla asistida por robot. Las variables clínicas y demográficas fueron obtenidas de historias clínicas electrónicas. Las variables continuas se resumieron mediante estadística descriptiva y las categóricas mediante frecuencias y porcentajes. **Resultados.** De los 100 pacientes, el 69% fueron mujeres, con una mediana de edad de 72 años (RIC 66–78). La mayoría de los procedimientos correspondieron a reemplazo total primario tricompartmental de rodilla. El bloqueo regional se utilizó en el 96% de los pacientes y el 94% recibió opioides postoperatorios. Los niveles de hemoglobina disminuyeron de 13,2 g/dL a 11,7 g/dL ($p < 0,001$). **Discusión.** La implementación inicial de la artroplastia asistida por robot mostró desenlaces perioperatorios y postoperatorios favorables, respaldando la factibilidad y seguridad de esta tecnología en contextos de ingresos medios. **Conclusiones.** La cirugía ortopédica robótica presentó resultados clínicos tempranos positivos y podría contribuir a

optimizar la precisión quirúrgica y la recuperación postoperatoria en cirugía de reemplazo articular.

Palabras clave: Artroplastia de Reemplazo de Rodilla; Artroplastia de Reemplazo de Cadera; Procedimientos Quirúrgicos Robotizados; Procedimientos Ortopédicos; Rodilla; Cadera; Cirugía Asistida por Computador; Implantación de Prótesis.

RESUMO

Introdução. A cirurgia ortopédica robótica teve início na Colômbia no final de 2023, representando um importante avanço tecnológico na cirurgia de substituição articular. O objetivo deste estudo foi descrever as características sociodemográficas, as variáveis perioperatórias e os resultados clínicos dos primeiros 100 pacientes submetidos a artroplastia total de quadril e joelho assistida pelo sistema robótico Mako® em uma instituição de alta complexidade na Colômbia. **Metodologia.** Foi realizado um estudo transversal entre dezembro de 2023 e julho de 2024, incluindo os primeiros 100 pacientes submetidos à artroplastia total de quadril e joelho assistida por robô. As variáveis clínicas e demográficas foram obtidas a partir de prontuários eletrônicos. As variáveis contínuas foram resumidas através de estatística descritiva, e as variáveis categóricas através de frequências e percentuais. **Resultados.** Dos 100 pacientes, 69% eram mulheres, com uma idade mediana de 72 anos (IIQ: 66–78). A maioria dos procedimentos correspondeu à artroplastia total primária tricompartmental de joelho. O bloqueio regional foi utilizado em 96% dos pacientes, e 94% receberam opioides no período pós-operatório. Os níveis de hemoglobina diminuíram de 13,2 g/dL para 11,7 g/dL ($p < 0,001$). **Discussão.** A implementação inicial da artroplastia assistida por robô revelou resultados perioperatórios e pós-operatórios favoráveis, corroborando a viabilidade e a segurança dessa tecnologia em contextos de média renda. **Conclusões.** A cirurgia ortopédica robótica apresentou resultados clínicos iniciais

positivos e pode contribuir para otimizar a precisão cirúrgica e a recuperação pós-operatória na cirurgia de substituição articular.

Palavras-chave: Artroplastia do Joelho; Artroplastia do Quadril; Procedimentos Cirúrgicos Robóticos; Procedimentos Ortopédicos; Joelho; Quadril; Cirurgia Assistida por Computador; Implantação de Prótese.

Introduction

In recent decades, robotic surgery has emerged as a tool for the benefit and optimization of procedures performed on patients, transforming the landscape of modern medicine (1). Such technology not only revolutionizes surgical practice with its safety (2), by reducing morbidity, increasing effectiveness, and minimizing risks, but also promises to significantly improve patients' quality of life. From safer procedures to faster recoveries, the benefits are evident and increasingly accessible in our region (3). Previous studies have reported reductions in postoperative complications, shorter hospital stays, and improved functional outcomes associated with robotic-assisted procedures (2,3), strengthening its clinical relevance.

As this technology advances, countries around the world have begun to adopt it (4). In Latin America, its beginnings date back to 1996 in Mexico (5). In Colombia, it arrived in mid-2008 with 'Da Vinci,' the first robot to assist in urological, gynecological, general surgeries such as bariatric and advanced laparoscopic procedures, as well as cardiovascular interventions (6). Globally, the use of robotic systems in orthopedic surgery has increased in recent years, particularly in high-income countries, where robotic-assisted arthroplasty has gained acceptance due to its precision and reproducibility (4).

The first robotic applications in orthopedic surgery began with the ROBODOC system(7,8). This robotic surgery arrived in Colombia at the end of 2023, contributing to the development

of more durable and modern implant technologies, which adapt to human anatomy, reduce pain, and shorten the rehabilitation process. Additionally, it has led to significant improvements in surgical techniques and times (9). Achieving the first 100 robotic surgeries in the country represents a significant milestone in the evolution of healthcare services, demonstrating a commitment to innovation and medical excellence. This study is designed as a cross-sectional study and aims to describe the sociodemographic characteristics and clinical outcomes of the first 100 patients who underwent total hip and knee arthroplasty assisted by the Mako® robotic arm (Stryker) at a high-complexity institution in Colombia.

Methodology

A cross-sectional study was conducted between December 2023 and July 2024, involving the first 100 patients who underwent total hip and knee arthroplasty using the Mako® robotic arm (Stryker) at the Hospital Internacional de Colombia. Adult patients with degenerative joint disease requiring replacement after failed conservative treatments were included, provided they consented to participate and adhered to perioperative guidelines.

Exclusion criteria included acute knee trauma, medical conditions contraindicating anesthesia, neuromuscular disorders affecting muscle strength, active osteoarticular infections, and patients in palliative care who would not benefit from joint replacement or lacked adequate social support. Additionally, patients were excluded if they lacked adequate social support, defined as the absence of a caregiver or support network to assist during the postoperative recovery period. Patients requiring joint replacement due to primary or metastatic oncological conditions, or those with soft tissue disorders limiting functionality, were excluded.

A thorough review of medical records was performed using the institutional electronic medical record system. Patient data were extracted from both the institutional electronic

health record system and the arthroplasty center of excellence database (hip and knee), stored in REDCap (Research Electronic Data Capture), under project code PID 1888. Data extraction was conducted using a structured data collection format designed by the research team to ensure consistency and completeness of the variables. The following variables were considered: age, sex, admission diagnosis, city of origin, area of residence, hospital stay, discharge status, surgery date, type of anesthesia, procedure, body mass index, pre-surgical planning days, pre-surgical transfusion, post-surgical transfusion, pre-surgical hemoglobin, post-surgical hemoglobin, regional block, post-surgical analgesics, post-surgical opioids, post-surgical Non-steroidal anti-inflammatory drugs (NSAIDs), antibiotic prophylaxis, antithrombotic prophylaxis, pre-surgical Visual Analogue Scale (VAS), Post-surgical VAS during hospitalization, and readmission. All statistical analyses were conducted using Stata® version 16. An analysis of hospital length of stay was conducted using Kaplan-Meier curves, considering discharge as the event of interest, with the aim of describing time to hospital discharge in this cohort.

The normality of continuous variables was assessed using the Shapiro-Wilk test. Descriptive statistics, including measures of central tendency and dispersion, were used to summarize these variables. Categorical variables were analyzed using absolute frequencies and percentages, box-and-whisker plots were used to visualize the variation in pre- and postoperative hemoglobin levels, as well as the VAS before and after surgery. An evaluation of hospital length of stay was conducted, with discharge as the outcome, using Kaplan-Meier analysis.

Ethical statement

This work was conducted in accordance with the prevailing guidelines for clinical research, with prior approval obtained from the institution's scientific committee CEI-2024-07461-9.

Informed consent was obtained from the patient. The study adhered to the guidelines established by Resolution 008430 of 1993 from the Ministry of Health of Colombia and the Declaration of Helsinki, originally outlined in 1964 and adapted to its latest revision in October 2013. The principles outlined in the Good Clinical Practice Guidelines and the ethical foundations inherent to this type of research design—respect for persons, beneficence, and justice as stated in the Belmont Report—were strictly followed.

Results

A total of 100 patients underwent robotic surgery, with 69% of the participants being female, and a median age of 72 years (IQR 66-78). Most participants were from the metropolitan area of Bucaramanga (AMB), with 33% from the city of Bucaramanga, followed by 29% from Piedecuesta. Additionally, among municipalities outside the AMB, Barrancabermeja accounted for 21% of the participants. Regarding residency, 98% of patients lived in urban areas. The majority of patients were overweight 41%, while 35% were obese. The most common initial diagnosis was gonarthrosis, accounting for 76% of cases, followed by knee disorders at 11% (Table 1.)

The median preoperative planning time was 14 days (IQR 8-22). The most frequent procedure performed was primary simple tricompartmental knee replacement (85%), followed by bicompartamental knee replacement (8%), complex primary tricompartmental knee replacement due to secondary osteoarthritis (5%), and simple hip replacement (2%).

In terms of prophylaxis, 99% of patients received antibiotics, and 97% were given anticoagulants prior to surgery. Regarding the type of anesthesia used, the combination of spinal anesthesia with sedation was the most common, accounting for 50% of the total procedures. Isolated spinal anesthesia was utilized in 30% of the cases, while general anesthesia was applied in 19%.

Additionally, 87% of the cohort was administered NSAIDs postoperatively. Transfusions were rare, with no preoperative transfusions reported, and only 2% of patients requiring them postoperatively. Two specific cases necessitated transfusions: the first involved a patient with a history of myocardial revascularization who was on anticoagulant therapy at the time of surgery, while the second involved a bilateral hip replacement performed via an anterior approach in a single procedure, where intraoperative instability prompted the need for blood product management. Notably, 97% of patients did not require readmission after surgery, three patients required readmission, with one patient being admitted twice. The main reasons for readmission were pain, edema, and localized warmth in the knee, although surgical site infection was ruled out in all cases. Another patient was readmitted due to a hematoma and pain in the right thigh, but imaging studies confirmed the absence of significant complications. The procedure demonstrated a 100% survival rate, defined as the absence of intraoperative mortality and no deaths during the immediate postoperative follow-up period, as well as no requirement for revision surgery or implant failure within the study timeframe (Table 2).

The probability of patients remaining hospitalized on the first day is 23% (95% CI: 15.32% to 31.62%). By the fifth day, this probability decreases significantly to 3% (95% CI: 0.08% to 0.77%) (Figure 1). Regarding variations in hemoglobin levels, the median pre-surgery was 13.2 g/dL (IQR 12.5-14.3), which decreased post-procedure to a median of 11.7 g/dL (IQR 11.1-12.5), with a p-value <0.001. Regarding pain assessment, the median VAS before surgery was 0 (IQR 0–2) and after surgery was 0 (IQR 0–3). Although the median remained unchanged, the wider interquartile range postoperatively indicates variability in pain perception, and this difference was statistically significant (p = 0.02) (Figure 2).

Additionally, exploratory stratification by BMI suggested that patients with obesity had slightly higher postoperative VAS dispersion, although no clinically significant differences were observed in other outcomes such as transfusion rates or length of stay.

Discussion

This cross-sectional study provides valuable insights into the first 100 patients who underwent robotic-assisted surgery with the Mako® system at a high-complexity institution in Colombia. The predominance of female patients and the advanced median age reflect the higher prevalence of arthroplasty in women and its association with age-related comorbidities (10). These findings are consistent with international reports, where robotic-assisted arthroplasty is more frequently performed in older populations with a higher burden of osteoarthritis and comorbidities (11,12).

The median preoperative planning time is in line with expectations for complex arthroplasties, reflecting efficient surgical management in this context (13). The geographic concentration of patients in urban areas highlights disparities in access to advanced surgical technologies, a pattern also described in other middle- and high-income countries (12). The high prevalence of overweight and obesity among the patients aligns with literature linking these conditions to an increased demand for joint replacements due to the additional stress placed on joints (14). Additionally, recent evidence suggests that obesity may influence postoperative pain perception and recovery trajectories, which is consistent with the slightly higher variability in postoperative VAS observed in this study (15).

Perioperative management was consistent with current standards, including near-universal use of antibiotic and antithrombotic prophylaxis (16). The anesthesia strategies employed likely contributed to adequate perioperative pain control and low complication rates (17). The observed decrease in hemoglobin levels is expected in this type of surgery, and the low

transfusion rate supports the effectiveness of perioperative blood management strategies (18).

Importantly, the absence of mortality and the 100% short-term survival rate, along with the low readmission rate, are consistent with studies from high-income settings, where robotic-assisted arthroplasty has demonstrated favorable safety profiles and low early complication rates (19).

Regarding pain outcomes, although median VAS values remained low, the increased interquartile range postoperatively indicates variability in pain perception, which is expected in the immediate postoperative period. This highlights the importance of individualized pain management strategies, as acute postoperative pain remains a relevant clinical outcome even in optimized surgical settings (20).

The findings support the feasibility, safety, and early effectiveness of implementing robotic-assisted arthroplasty in middle-income settings, contributing valuable real-world evidence from a high-complexity institution in Colombia. These results may inform clinical decision-making and support the expansion of this technology in similar healthcare contexts. However, the cross-sectional design limits causal inference, and the single-center setting may affect generalizability. Additionally, the short follow-up period precludes evaluation of long-term outcomes such as implant survival and functional recovery. Future studies should incorporate longitudinal designs, larger sample sizes, and comparative analyses with conventional techniques to better assess long-term outcomes, cost-effectiveness, and patient-reported outcomes.

Conclusions

The findings of this study suggest that the introduction of robotic-assisted surgery in orthopedics in Colombia has been feasible and may be associated with favorable

perioperative outcomes, including effective risk management, optimized surgical times, and adequate postoperative recovery. The experience derived from these initial 100 cases provides a foundation for future research, particularly studies comparing robotic and conventional techniques, as well as for the continued refinement of surgical protocols in this evolving field.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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Statement on the use of artificial intelligence

No artificial intelligence was used.

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Table 1. Descriptive Analysis of Sociodemographic Characteristics.

Variable	Category	n	%
Age	Median (IQR)	72	(66-78)
Sex	Female	69	69
	Male	31	31
Body Mass Index	Underweight	2	2
	Normal	16	16
	Overweight	41	41
	Obesity I	29	29
	Obesity II	5	5
	Obesity III	1	1
	No data	6	6
City of Origin	Bucaramanga	33	33
	Piedecuesta	29	29
	Barrancabermeja	21	21
	Floridablanca	8	8
	Girón	2	2
	Other	7	7

Area of Residence	Rural	2	2
	Urban	98	98
Admission Diagnosis	Arthrosis	7	7
	Fracture	2	2
	Gonarthrosis	76	76
	Other Conditions	4	4
	Knee Disorders	11	11

Source: prepared by authors

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Table 2. Descriptive Analysis of Clinical Characteristics.

Variable	Category	n	%
Preoperative (days)	Planning Median (IQR)	14	(8-22)
Procedure	Primary Simple Tricompartimental Total Prosthetic Knee Replacement	85	85
	Bicompartimental Total Knee Replacement	8	8
	Primary Total Prosthetic Replacement	5	5
	Complex Tricompartimental Knee Replacement (Secondary Osteoarthritis)		
	Primary Simple Total Hip Prosthetic Replacement	2	2
Antibiotic Prophylaxis	Yes	99	99
Antithrombotic Prophylaxis	Yes	97	97
Type of Anesthesia	Spinal anesthesia+ Sedation	50	50
	Spinal anesthesia	30	30
	General	19	19
	General + Sedation	1	1
Regional Block	Yes	96	96
Postoperative Analgesia	Yes	98	98

Postoperative Opioids	Yes	94	94
Postoperative NSAIDs	Yes	87	87
Transfusions	Yes	2	2
Preoperative Transfusions	No	100	100
Postoperative Transfusions	Yes	2	2
Readmissions	Yes	3	3
Patient Status	Alive	100	100

Source: prepared by authors

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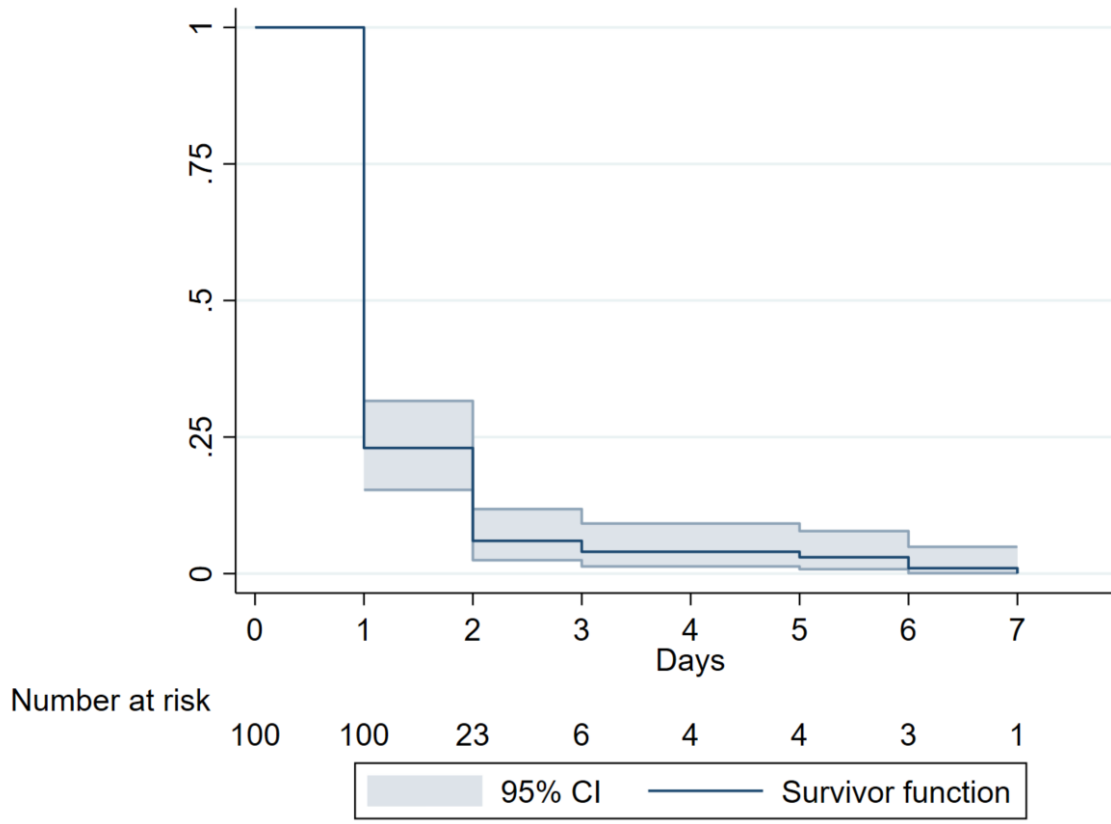


Figure 1. Hospital Stay in Patients with Robotic Surgery.

Source: prepared by authors

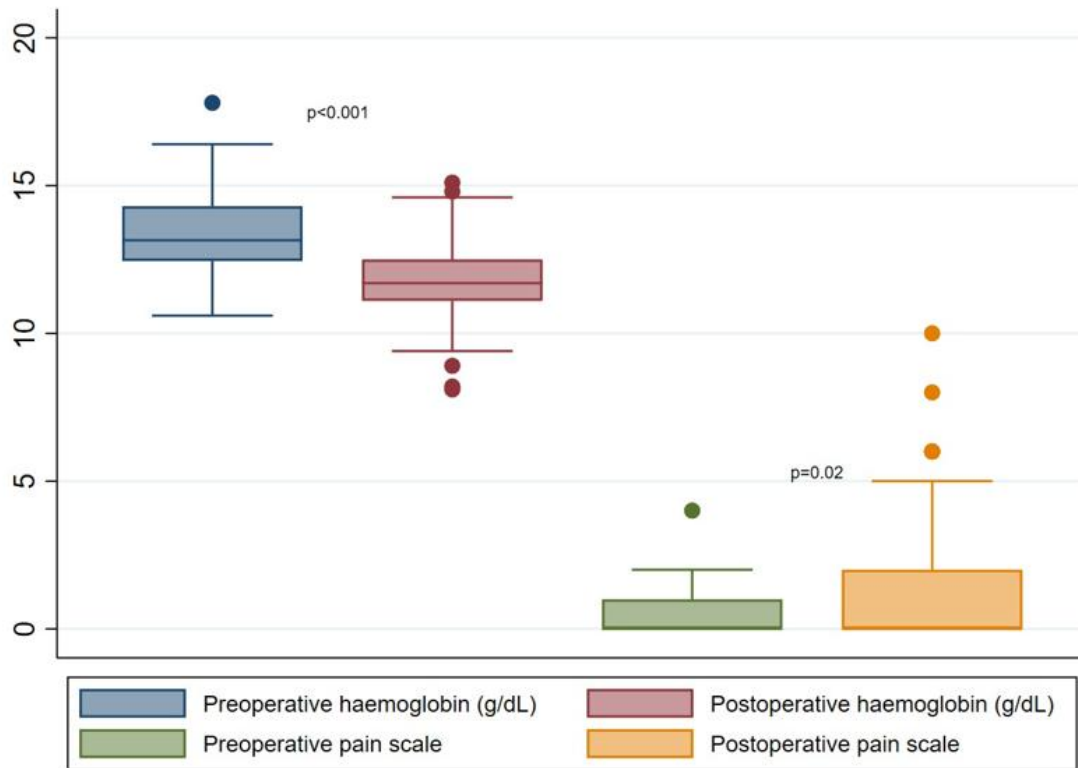


Figure 2. Variation in Hemoglobin and Pain in Pre- and Post-Surgical Patients.

Source: prepared by authors