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Incidence of failure-to-rescue after coronary artery bypass grafting: a multicenter observational study from the REPLICCAR II registry in Brazil

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Abstract

Background Failure-to-rescue refers to the rate of failure amongst healthcare teams in reversing complications that occur during a patient's hospitalization. This study aimed to investigate the failure-to-rescue rate following coronary artery bypass grafting (CABG).

Methods Cross-sectional cohort study of the multicenter database "*Registro Paulista de Cirurgia Cardiovascular* II" (REPLICCAR II), which includes data from nine reference centers for cardiac surgery in São Paulo State. The study population included patients > 18 years of age who had undergone primary and isolated CABG surgery between 2017 and 2019 in Brazil. The outcome measured was failure-to-rescue (including death and the development of postoperative complications: prolonged ventilation time, stroke, reoperation, and kidney injury). The study used the Society of Thoracic Surgeons (STS) risk score to calculate the expected complication rates.

Results Out of the 3964 patients, 439 developed one or more of the analyzed complications, and out of those, 94 died (2.37% of the full sample). The standardized mortality ratio (SMR) for patients who developed one complication was 8.84% (10.7%/1.21%), whereas those with two combinations of complications had an SMR of 32.34% (53.68%/1.66%) and three complications had an SMR of 42.02% (50%/1.19%). However, patients who progressed without the analyzed complications had an SMR of 0.95% (0.74%/0.80%).

Conclusion The REPLICCAR II database revealed a failure-to-rescue rate of 21.41% (94/439), and the SMR increased progressively according to the greater number of complications. Our findings emphasize the need to measure the impact of early diagnosis and effective hospital team response by parameterizing the risk of expected death after severe complications.

Trial registration The REPLICCAR Registry and The Statewide Quality Improvement Initiative, ID NCT05363696.

Keywords Failure-to-rescue, Coronary artery bypass surgery, Postoperative complications, Hospital mortality, Quality initiatives

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Introduction

Mortality outcomes after cardiovascular surgery have decreased in recent years [1–3]; however, this positive trend has yet to be observed globally [4–6]. To address this issue, databases have emerged as opportunities for continuous improvement. By identifying structural and procedural problems, databases provide the opportunity to implement data-driven strategies [6], which enables a cycle of dynamic improvements, using increasingly accurate and patient-centered metrics, allowing the creation of high-performance teams [5, 6].

Studies have shown that high-performance hospitals are characterized by a low mortality rate, even when a significant incidence of postoperative complications occurs [7–9], because these complications are multifactorial and might be related to the patient profile and complexity of the procedure performed [7, 8, 10, 11]. Although risk scores can help predict mortality, currently no technique is available to predict complications and mortality risk in real time for patients under observation.

Due to this knowledge gap, failure-to-rescue emerges as a metric for evaluating observed deaths after a complication, which reflects the performance of healthcare teams, because it portrays the failure to identify, diagnose, and treat complications that lead to death [7, 10].

The STS Quality Measurement Task Force database provides evidence on expected mortality rates for patients who are undergoing coronary artery bypass grafting (CABG) with complications and includes failure-to-rescue as a new performance metric for adult cardiac surgery [10]. Because this metric is still unknown in Latin America, this analysis aimed to evaluate the failure-to-rescue rate at São Paulo centers participating in the *Registro Paulista de Cirurgia Cardiovascular II* (REPLICCAR II).

Methods

This cross-sectional cohort study utilized data from the prospective multicenter database REPLICCAR II, where data collection was performed prospectively and observationally, including patients undergoing primary and isolated CABG surgeries between July 2017 and June 2019 at nine reference hospitals in the state of São Paulo. This retrospective subanalysis was conducted for the purpose of quality analysis by the responsible unit at the central institution of the REPLICCAR II database.

All data were entered into the REDCap platform, in an area dedicated to the REPLICCAR II project, by trained health professionals. Quality audits were carried out periodically to verify data accuracy, integrity, and consistency and are available upon request from the Ethics Committee representing the project [12].

The authors followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [13] guidelines in this manuscript.

Data collection and organization

Data collection and extraction were performed through the REDCap platform, with those involved in the process receiving appropriate training to perform this function. In addition, the REPLICCAR II data quality team worked diligently to ensure the integrity and consistency of records, thereby ensuring the validity of clinical outcomes for healthcare quality [12].

The REPLICCAR II study included patients over 18 years of age, undergoing isolated CABG with elective or urgent surgical status ($n=4049$) during the period of July 2017 to June 2019. Patients who underwent preoperative dialysis ($n=85$) were excluded from this present analysis to avoid overestimation of kidney injury as a complication after CABG, resulting in a total sample size of 3964 patients.

The definitions of variables and the calculation of risk prediction were based on version 2.9 of the STS Adult Cardiac Surgery Database [14]. Similarly, the definition of failure-to-rescue was established based on the publication from the STS Quality Measurement Task Force [10]. For this purpose, failure-to-rescue was defined as operative mortality in patients who experienced one or more of the following complications: prolonged ventilation time, stroke, reoperation, and acute kidney injury (brief definitions in Table 1), totaling 94 patients from the evaluated sample, as shown in Fig. 1.

Statistical analysis

R software version 4.0.2 was used to perform all the analyses in this study. For descriptive analysis, continuous variables are expressed as mean, median, standard deviation and quartiles (range 25% and 75%), whereas categorical variables are expressed as frequencies and percentages. For the comparison of two groups with continuous variables, the t-test was used for normally distributed variables (Anderson–Darling test) and nonparametric tests were used for the other variables. The Mann–Whitney test was used for homogeneous variables and the Brunner-Munzel test was used for heterogeneous variables. Fisher's exact test or the chi-square test was used for categorical variables. The standardized mortality ratio (SMR) was calculated by the ratio of observed numbers of deaths in the cohort to the number of expected deaths for this same cohort.

Ethics and informed consent

This study was approved by the institutional research ethics committee. The free and informed consent was

Table 1 Definition of failure-to-rescue variables

Variable	Definition
Operative mortality	All deaths, occurring during the hospitalization in which the operation was performed, even if after 30 days (including patients transferred to other acute care facilities); and all deaths, occurring after discharge from the hospital until the thirtieth postoperative day
Prolonged ventilation time	Patients who had prolonged postoperative pulmonary ventilation > 24.0 h. The hours of postoperative ventilation time include OR exit until extubation, plus any additional hours following reintubation
Stroke	Neurological deficit of abrupt onset caused by a disturbance in blood supply to the brain that did not resolve within 24 h
Reoperation	Reoperation for any cardiac reason, reexplored for mediastinal bleeding with or without tamponade either in the ICU or returned to the operating room, prosthetic or native valve dysfunction, intervention of coronary graft occlusion due to acute closure, thrombosis, technical or embolic origin, reintervention for Myocardial Ischemia, postoperative aortic reintervention, or other cardiac reasons
Acute kidney injury	Indicate whether the patient had acute renal failure or worsening renal function resulting in one or both of the following: Increase in serum creatinine level 3.0 × greater than baseline, or serum creatinine level ≥ 4 mg/dL. Acute rise must be at least 0.5 mg/dL, and/or a new requirement for dialysis postoperatively

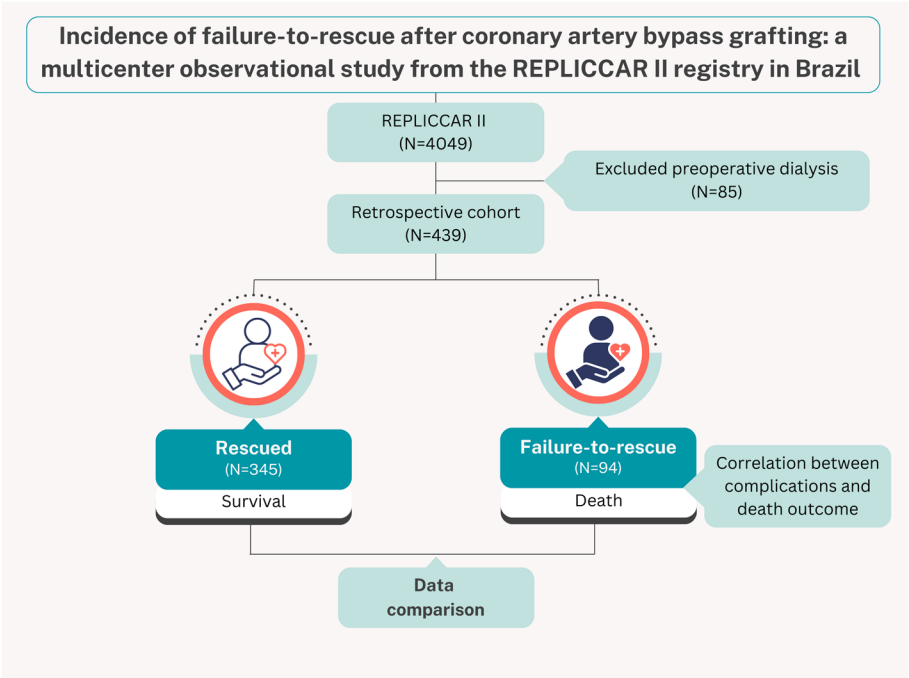

Fig. 1 Study flowchart. REPLICCAR II: *Registro Paulista de Cirurgia Cardiovascular* II

waived due to the analysis of pre-established data logs. We declare that all methods were performed in accordance with relevant guidelines and regulations.

Results

In this study, out of 3964 patients, 439 had one or more complications under analysis; amongst them, 94 evolved to death, which characterizes the occurrence of failure-to-rescue in 21.41% of the patients in the group.

According to the patient profiles (Tables 2 and 3), patients who developed failure-to-rescue were older than the group of rescued patients ($p=0.008$) and mostly females ($p=0.046$). They also had a higher risk of mortality ($p=<0.001$), acute kidney injury ($p=0.013$), reoperation ($p=0.014$), prolonged ventilation ($p=0.001$), and stroke ($p=0.019$) as estimated by the STS.

Among the patients who did not develop the complications chosen for this analysis, the SMR was 0.95% (0.74%/0.80%). On the other hand, the failure-to-rescue in patients who evolved with one complication was 8.84% (10.7%/1.21%), whereas those with a combination of two complications was 32.34% (53.68%/1.66%)

Table 2 Characterization of the analyzed patients

Variables	Failure-to-rescue (*n* = 94)		Rescued (*n* = 345)		*p*-value
	n	%	n	%	
Preoperative characterization					
Median age (IQR[a])	70 (64–76)		67 (62–73)		0.008
Sex					0.046
Male	56	59.57%	243	70.64%	
Preoperative creatinine, mean, ± SD[b]	1.34, ± 0.57		1.33, ± 0.63		0.779
LVEF[c] (%), mean, ± SD	52.00, ± 17.00		51.65, ± 18.00		0.905
Diabetes mellitus treatment					0.332
Uncontrolled	0	0%	6	3.16%	
Oral hypoglycemic agents	28	50.91%	113	59.47%	
Insulin	23	41,825	56	29.47%	
AMI[d]	52	55.91%	189	55.1%	0.050
Previous Stroke	8	50%	24	40.68%	0.642
CCS[e] grading of angina pectoris					0.715
I	42	45.16%	160	47.02%	
II	20	21.51%	84	24.78%	
III	18	19.35%	59	17.04%	
IV	13	13.98%	36	10.62%	
NYHA[f] classification					0.122
I	54	58.7%	236	69.41%	
II	12	13.04%	44	12.94%	
III	18	19.57%	38	11.18%	
IV	8	8.7%	22	6.47%	
STS[g] mortality (%), mean ± SD	2.08%, ± 2.01%		1.29%, ± 1.09%		< 0.001
STS stroke (%), mean ± SD	1.51%, ± 1.15%		1.22%, ± 0.80%		0.019
STS kidney failure (%), mean, ± SD	3.21%, ± 4.86%		1.85%, ± 2.65%		0.013
STS prolonged orotracheal intubation (%), mean, ± SD	8.18%, ± 7.97%		5.25%, ± 3.77%		0.001
STS reoperation, mean ± SD	2.41%, ± 0.71.025%		2.10%, ± 0.75%		0.014

[a] *IQR* Interquartile range

[b] *SD* standard deviation

[c] *LVEF* left ventricular ejection fraction

[d] *AMI* acute myocardial infarction

[e] *CCS* Canadian Cardiovascular Society

[f] *NYHA* New York Heart Association

[g] *STS* The Society of Thoracic Surgeons

Table 3 Occurrence of complications in patients during hospitalization

Variables	Total (*N* = 3964)		Failure-to-rescue (*n* = 94)		Rescued (*n* = 345)		*p*-value
	n	%	n	%	n	%	
Reoperation	67	1.69%	15	15.96%	52	15.96%	0.872
Prolonged orotracheal ventilation	176	4.44%	64	68.09%	112	32.56%	< 0.001
Stroke	53	1.34%	14	14.89%	39	11.34%	0.373
Acute kidney injury	270	6.81%	68	72.34%	202	58.72%	0.001
Hospital mortality after analyzed the complications	94	2.37%	94	100%	0	0%	< 0.001

and those with three complications was 42.02% (50%/1.19%), as shown in Fig. 2 and Table 4. Our analysis did not detect the combination of all four complications.

Discussion

Our results indicate that the failure-to-rescue rate in the São Paulo database REPLICCAR II (21.41%, 94/439) is comparable to the rates reported in previous studies performed in other countries [7, 10, 15], confirming that

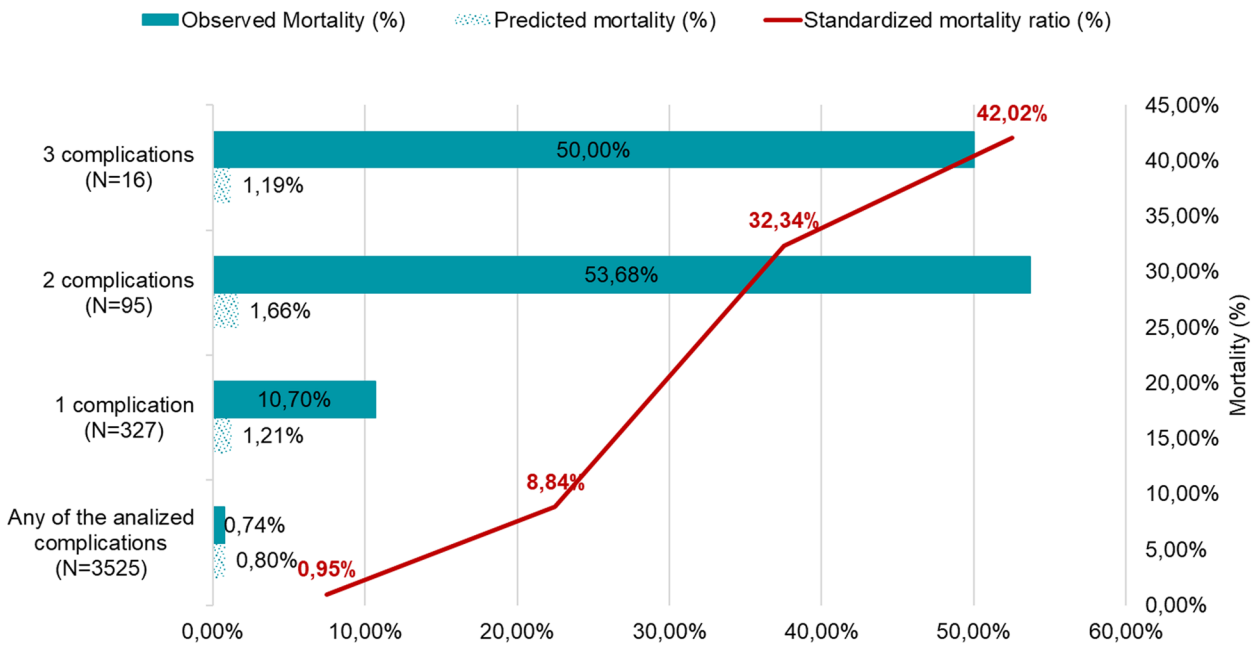

Fig. 2 Mortality rate predicted and observed regarding the progressive combination of complications

Table 4 Relationship between postoperative events and deaths in the database

Complications					Deaths (n)	Total (N)	Observed mortality (%)	Predicted mortality (mean%)	SD[a]
0					26	3525	0.74	0.80	0.67
1	**Prolonged orotracheal ventilation**				11	83	13.25	1.18	1.29
1		**AKI[b]**			15	179	8.38	1.43	1.08
1			**Reoperation**		6	41	14.63	1.00	0.72
1				**Stroke**	3	24	12.50	1.22	0.64
2	**Prolonged orotracheal ventilation**	**AKI**			41	60	68.33	2.37	2.17
2	**Prolonged orotracheal ventilation**		**Reoperation**		2	8	25.00	1.21	0.65
2	**Prolonged orotracheal ventilation**			**Stroke**	3	11	27.27	1.75	2.54
2		**AKI**	**Reoperation**		1	7	14.29	1.84	1.86
2		**AKI**		**Stroke**	4	9	44.44	1.14	0.99
2			**Reoperation**	**Stroke**	0	0	-	-	-
3	**Prolonged orotracheal ventilation**	**AKI**	**Reoperation**		4	7	57.14	1.57	1.25
3	**Prolonged orotracheal ventilation**	**AKI**		**Stroke**	2	6	33.33	1.33	0.77
3	**Prolonged orotracheal ventilation**		**Reoperation**	**Stroke**	1	1	100.00	1.12	-
3		**AKI**	**Reoperation**	**Stroke**	1	2	50.00	0.73	0.14

[a] *SD* standard deviation

[b] *AKI* acute kidney injury

observed mortality increases progressively according to the greater number of combinations of complications.

Failure-to-rescue emerges as a relevant metric in quality analysis, adding value to the known variables, mortality and morbidity, which are traditionally evaluated, providing an opportunity to evaluate the institution and its effectiveness in reversing hospital-acquired complications and preventing deaths. A low failure-to-rescue rate, despite a high incidence of complications, reflects a high-performance hospital team and adequate infrastructure. On the other hand, a high failure-to-rescue rate indicates the need for the hospital to readjust and reassess the clinical experience, as well as the institutional resources, to enhance patient care [7–9].

Currently, no consensus exists on the complications correlated with failure-to-rescue in cardiac surgery, and the heterogeneity of variables in the scientific literature is significant [7, 8, 10, 15, 16]. This study followed the method presented by The Society of Thoracic Surgeons (STS) [10], which will soon incorporate this new metric into its risk prediction calculator. However, it is important to emphasize that current risk scores are unable to monitor and update patient evolution as they evolve.

The inflexibility of current risk scores blinds healthcare professionals to the risk of their patients during hospitalization, which impairs the therapeutic decision-making process. In 2016, Ranucci et al. [17] proposed a classification strategy at two different times to update the indices according to the patient's status. This strategy aims to address the frustration related to the attempt to stratify the risk of high-risk patients in cardiac surgeries and the discrepancy between the predicted and observed values. Such an approach can improve the performance of the outcome predictor scores. Furthermore, with technological advancements, it is desirable that healthcare applications and platforms, such as Kamay [18], Cardux [19], or the Prehab APP [20], could enable real-time, personalized, and predictive patient care, thus feeding into continuous improvement cycles [18–21]. Given this observation, we believe that the new metric of STS [10], associated with the strategy of reclassification of the patient's risk score during the hospital stay [17], might be a valuable tool to reliably monitor the patient's status. However, a study focused on this analysis should be carried out.

In our analysis, patients in the failure-to-rescue group had a higher predicted risk of mortality, acute kidney injury, reoperation, and prolonged ventilation as estimated by STS, compared with the Rescued group. In addition, age and sex were also a differential between groups, which represents that the population was potentially more complex. Previous studies have shown a correlation between advanced age of the patient and higher rates of failure-to-rescue [8, 15], as well as female patients [22] highlighting the knowledge gap surrounding the failure-to-rescue in the fragile and female populations. This finding underscores the challenge of accurately assessing a patient's risk and strategically planning the procedure, as failure to identify factors related to the risk of these complications can culminate in a cascade of events leading to failure-to-rescue, mainly in hospitals [9, 23] with lower surgical volume [9, 23] or without teams aligned for high-performance care.

Comparing the results of this study and STS's database [10], we observe a similar overall mortality rate, with 2.37% in our study and 2.6% in the STS. We attribute these outcomes to the REPLICCAR project's emphasis on quality improvement through data-driven strategies [5, 6]. The rates of analyzed complications were also closely aligned, with 11.07% in REPLICCAR II and 12% in STS. Additionally, failure-to-rescue rates were also comparable between the studies, showing 21.24% and 21.41% respectively. Both datasets further demonstrate a trend: as complication combination increases, so does the failure-to-rescue rate, underscoring the impact of cumulative complications on patient outcomes across populations, even in different socioeconomic levels, countries, and healthcare context.

The quantification of healthcare quality reflects a constantly evolving challenge, especially regarding patients referred for high-risk cardiac surgeries. Value-based medicine has gained increasing prominence in society through the pay for performance model and the search for better outcomes for patients undergoing surgical procedures, which is already a reality in the Latin American scenario [24, 25]. Recognition and continuous efforts to reduce failure-to-rescue rates are challenges that emerge and stand out in the current literature and are closely linked to institutional competence.

This pioneering study in the Latin American scenario presents the failure-to-rescue in patients who had one or more complications after CABG, which is relevant as it alerts hospital managers, healthcare professionals, and especially patients about this metric's potential to identify care difficulties, providing the opportunity to create strategies within the concepts of continuous improvement in cardiac surgery. Upcoming analyses should bring results on external validations of the new STS [10] calculator and comparisons of scores predicting the risk of failure-to-rescue by hospitals.

Study limitations

This study aimed to determine the current failure-to-rescue rate in São Paulo centers participating in REPLICCAR II. Due to ethical considerations, we did not analyze each institution separately, thus, the analysis may have

been biased related due to variation in patient profiles, clinical experience, and available resources among the hospitals. As the failure-to-rescue rate is a metric used to evaluate hospital quality and care teams, future studies should include individualized analyses for each institution, allowing for the development of specific strategies for each center and/or care team.

Because of the heterogeneity of variable selection to characterize failure-to-rescue in cardiac surgeries [7, 8, 10, 15, 16], we followed the methodology proposed by the STS [10]. However, the authors warn about the importance of evaluating complications such as surgical wound infection in future studies, because the prevalence is divergent across countries and considerable in our reality [25–27]; however, these studies have been excluded from the calculator thus far.

In our analysis, we did not observe the combination of the four complications studied, and we believe that this fact is attributed to the small sample size. However, despite this limitation, our pioneering study in Brazil warns about the current scenario, which tends to underestimate low-risk patients and stiffens the risk prediction through scores that do not follow patient evolution. This can lead to unexpected clinical worsening, triggering unfavorable outcomes.

Conclusions

In conclusion, in this current analysis, the REPLICCAR II database revealed a failure-to-rescue rate of 21.41% (94/439), and the SMR increases progressively according to the greater number of complications. It is strongly recommended to use the failure-to-rescue metric to identify weaknesses in the care of patients undergoing CABG. This will facilitate the creation of strategies and institutional improvements through the data, as the reapplication of the score must be considered during the patient's hospital stay.

Abbreviations

CABG	Coronary artery bypass grafting
STS	The Society of Thoracic Surgeons
SMR	Standardized mortality ratio
SD	Standard deviation
AKI	Acute kidney injury
IQR	Interquartile range
LVEF	Left ventricular ejection fraction
AMI	Acute myocardial infarction
CCS	Canadian Cardiovascular Society
NYHA	New York Heart Association

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Authors' contributions

GBB: conception, design of the work, data acquisition, analysis, interpretation of data, writing and review of the manuscript. RDD: interpretation of data and review of the manuscript. PGMBS: data acquisition and review of the manuscript. MAN: data acquisition and review of the manuscript. MAPO: data acquisition and review of the manuscript. VPC: data acquisition and review of the manuscript. MGT: data acquisition and review of the manuscript. LAFL: interpretation of data and review of the manuscript. LAH: interpretation of data and review of the manuscript. JPZ: interpretation of data and review of the manuscript. FBJ: interpretation of data and review of the manuscript. OAVM: conception, design of the work, interpretation of data, and review of the manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was submitted and approved by the institutional Research Ethics Committee (CAPPesq) under number: 66919417.6.1001.0068, and Sistema de Documentação Científica (SDC): 4506/17/006. The free and informed consent was waived due to the analysis of pre-established data logs. We declare that all methods were performed in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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