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Association between time of day for rapid response team activation and mortality

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ABSTRACT

Purpose: To evaluate the frequency of rapid response team (RRT) calls by time of day and their association with in-hospital mortality.

Materials and methods: This was a retrospective cohort study of all RRT calls at a tertiary teaching hospital in Porto Alegre, Brazil. Patients were categorized according to the time of initial RRT activation. Activations were classified as daytime (7:00–18:59) or nighttime (19:00–6:59). The primary outcome was in-hospital mortality rate. The secondary outcome was ICU admission within 48 h of RRT assessment.

Results: During the study period, 4522 patients were included in the final analysis. Cardiovascular and respiratory changes were more common causes of nighttime activation, whereas neurological and laboratory changes were more common during the daytime. The in-hospital mortality rate was 23.9% (1081/4522). Nighttime RRT calls were not associated with worse outcomes than daytime calls. However, a decrease in the number of calls was observed during nursing handover periods (7:00, 13:00 and 19:00). Two time periods were associated with increased adjusted odds for mortality: 12:00–13:00 (adjusted OR 2.277; 95% CI 1.392–3.725) and 19:00–20:00 (adjusted OR 1.873; CI 1.873; 95% 1.099–3.190).

Conclusion: We found that nighttime RRT calls were not associated with worse outcomes than daytime RRT calls. However, a decrease in the number of calls and higher mortality was observed during nursing handover periods.

1. Introduction

Previous studies have shown that adverse events such as in-hospital cardiac arrest (IHCA), unplanned intensive care unit (ICU) admission and unexpected death are, in most cases, preceded by objective signs of deterioration in hospitalized patients [1-4]. First described in the medical literature in the early 1990s [5], rapid response team (RRT) care for patients with acute clinical deterioration aims to reduce cardiac arrest and mortality [6,7].

The proper functioning of the rapid response system depends on the recognition of the patient with acute deterioration, timely activation by the afferent limb, and effective intervention of the efferent limb [8,9]. Considering that the amount and level of training of hospital staff available at night can vary greatly in relation to those available during the day [10], the performance of both limbs can be compromised at night. A lower nurse-to-patient ratio and less experienced staff (both in the RRT and ward) at night may contribute to worse outcomes in patients with nighttime RRT activation. Three studies evaluated the relationship between activation time and patient mortality [11-13]. In these studies, nighttime RRT activation was associated with a higher risk of mortality. No study in Brazil has evaluated this aspect of RRTs.

This study aimed to evaluate the frequency of RRT calls by the time of day and their association with in-hospital mortality. Our null hypothesis was that the in-hospital mortality rate is not affected by call

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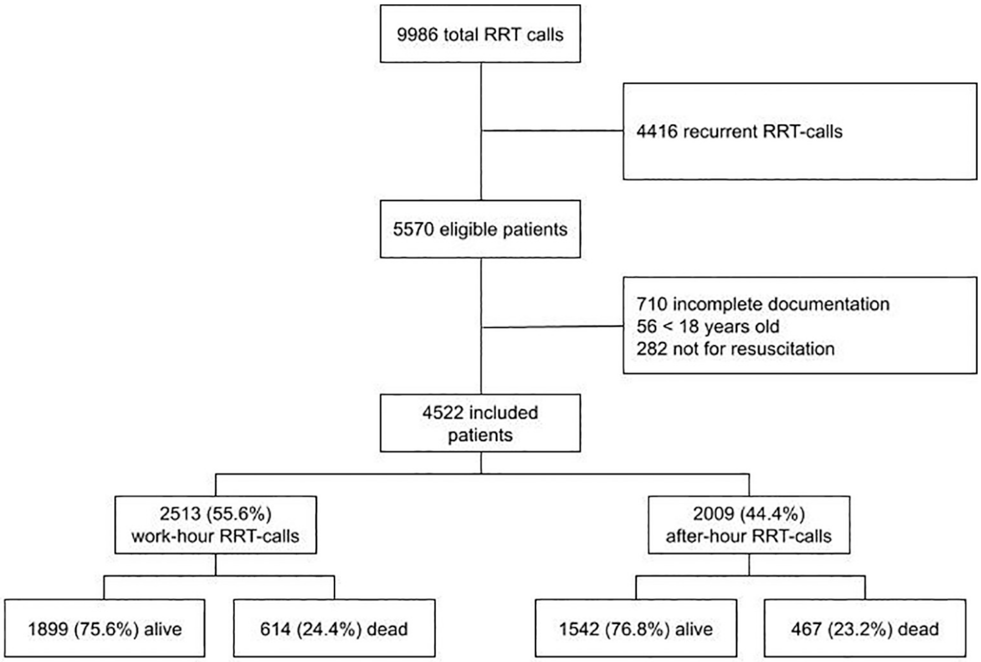

Fig. 1. Flow chart of study patients.

shifts in a hospital that maintains a constant RRT configuration and nurse-to-patient ratio 24 h a day.

2. Materials and methods

2.1. Ethics

The study was approved by the ethics committee of Hospital de Clínicas de Porto Alegre (CAAE 56302116.1.0000.5327).

2.2. Details of the hospital

This was a retrospective analysis of prospectively collected data for all RRT calls occurring at the Hospital de Clínicas de Porto Alegre (HCPA) from July 2014 to June 2018. The HCPA is a tertiary teaching hospital with 842 beds, including 51 ICU beds and approximately 30,000 annual hospitalizations.

2.3. Details of the RRT

The RRT was implemented in July 2014. A dedicated intensivist is available for the RRT 24/7, with the assistance of ward nurses and respiratory therapists. The RRT operates 24 h a day, seven days a week, with the same composition. The system can be activated by any hospital member according to the predefined criteria. Triggers to activate RRT are based on acute changes in heart rate (<40 or > 140 beats per minute), systolic blood pressure (<80 mmHg or between 80 and 90 mmHg with symptoms), respiratory rate (<8 or > 35 breaths per minute), level of consciousness (Glasgow coma scale reduction ≥2 points), oxygen saturation (<90%), risk of airway maintenance (need for intubation, tracheal suction, or tracheostomy care), prolonged seizure (more than five minutes), or laboratory triggers (pH <7.3, bicarbonate <12 mEq/L, and lactate >3.0 mmol/L). To describe the results, heart rate and systolic blood pressure were classified as cardiovascular triggers, respiratory rate, need for airway management, and oxygen saturation as respiratory triggers, and seizure and altered level of consciousness as neurological triggers.

2.4. Details of ward nursing handover and staffing ratios

Regarding the nursing staff, the nurse-to-patient ratio was the same during the day and night. The times of ward nursing handovers were 7:00, 13:00, and 19:00. In addition to RRT, there is another team composed of a senior internist and residents. This service is activated based on demand, particularly when nurses express concerns or there are alterations in vital signs that do not meet the criteria for a RRT activation. It operates specifically between the hours of 18:00 and 7:00.

2.5. Study cohort

All patients with RRT activation during the study period were included. Patients with documented do not resuscitate orders, those under 18 years of age and those with incomplete data were excluded. We do not have data related to cardiac arrest cases because the care for these cases is managed by another team. We categorized patients based on the time of initial RRT activation, distinguishing between daytime (7:00–18:59) and nighttime (19:00–6:59) activations. The activation shift period corresponds to the time when a RRT was activated to assess a patient's condition. Patients with multiple activations during admission were categorized based on the time of first activation.

2.6. Details of data collected

Patient information, reason for activation, occurrence of delay in activation, and whether the patient was admitted to the ICU were collected by RRT staff at the time of patient assessment. The outcome at hospital discharge was verified through a review of medical records. A delayed RRT call was defined as the documented RRT criteria for which no RRT call was made during the period from 30 min to 24 h prior to an RRT review. The primary outcome was in-hospital mortality. The secondary outcomes were ICU admission within 48 h of RRT assessment and multiple activations.

2.7. Statistical analysis

Continuous variables are presented as mean ± SD or median and interquartile range (IQ), while categorical variables are presented as

Table 1
Characteristics of patients with daytime and nighttime Rapid Response Team activation.

Variable	Daytime (07:00–18:59) (n = 2513)	Nighttime (19:00–06:59) (n = 2009)	P value
Age, years, median (IQR)	63.0 (52.0–72.0)	64.0 (52.0–73.0)	0.453
Male sex, n (%)	1301 (51.8%)	1034 (51.5%)	0.857
Who generated the call, n (%)			
Nurse	2043 (81.3%)	1767 (88.0%)	<0.001
Attending physician	379 (15.1%)	55 (2.7%)	<0.001
Other team	91 (3.6%)	187 (9.3%)	<0.001
Type of admission, n (%)			
Medical	1542 (61.4%)	1209 (60.2%)	0.425
Surgical	948 (37.7%)	779 (38.8%)	0.479
Obstetric	23 (0.9%)	21 (1.0%)	0.652
Delayed activation, n (%)	326 (13.0)	259 (12.9)	0.964
Reason for call, n (%)			
Cardiovascular	1076 (42.8%)	945 (47.0%)	0.005
Respiratory	913 (36.3%)	921 (45.8%)	<0.001
Neurologic	326 (13.0%)	162 (8.1%)	<0.001
Laboratory	238 (9.5%)	40 (2.0%)	<0.001
Staff worry	256 (10.0%)	90 (4.5%)	<0.001
Multiple activations	1006 (40.0%)	838 (41.7%)	0.253
Admitted to ICU, n (%)	552 (22.0%)	416 (20.7%)	0.307
In-hospital mortality, n (%)	614 (24.4%)	467 (23.2%)	0.362

IQR: interquatil range; ICU: intensive care unit.

absolute numbers and percentages. The Student's t-test or Mann–Whitney test was used for continuous variables, and the chi-square test for categorical variables. An alluvial flow diagram was constructed to illustrate the trajectory of patients from the activation shift to the primary outcome. A multivariate model was constructed to identify variables independently associated with in-hospital mortality, with time of activation maintained as a variable of interest, along with other variables defined a priori as plausibly associated with the outcome. A secondary analysis was performed using time of day as the exposure variable, with 15:00–16:00 as the reference hour, to evaluate changes in adjusted mortality over the course of the day. A post hoc analysis was also conducted to assess the association between in-hospital mortality and nursing handover time. Adjusted odds ratios (ORs) with 95% CI were calculated, and statistical significance was set at $p < 0.05$. Statistical analysis was performed using SPSS version 22.0 (SPSS, Chicago, IL, USA).

3. Results

3.1. Details of RRT calls

A total of 9220 RRT calls were made for 5570 patients during the study period. Of these, 1048 patients were excluded, leaving 4522 patients for the final analysis (Fig. 1). The characteristics of the included patients are presented in Table 1. The reasons for RRT activation were significantly different between the daytime and nighttime. Cardiovascular and respiratory changes were more common causes of nighttime activation, while neurological and laboratory changes were more common during the daytime. There was no difference in the prevalence of delay in calls between the daytime and nighttime. In addition, there was no difference in the prevalence of delay in calls between the time of nursing handover (14.1%) and other times (12.8%) ($p = 0.471$).

3.2. Difference in mortality and secondary outcomes according to shift

The in-hospital mortality rate of the included patients was 23.9% (1081/4522). No difference in mortality or ICU admission was observed based on the timing of activation shift. To illustrate the patient trajectory from the time of activation shift to the primary outcome, we have included a visualization in Fig. 2. In addition, there were no differences in multiple activations based on the timing of the first activation shift (Table 1). Logistic regression adjusted for patient variables, delayed calls, multiple activations, and activation triggers showed no association between nighttime RRT activation and the primary outcome (Table 2). The frequency of calls and risk of mortality throughout the day are shown in Fig. 3.

3.3. Change in RRT activation around nursing handover times

RRT activation was greater in the early morning and afternoon hours and at the end of the night shift, which coincided with the routine observation of vital signs and proximity to the nursing handover. In addition, we noticed a decrease in the number of calls at the time of the nursing handover (7:00, 13:00, and 19:00). Two statistically significant time periods were associated with increased adjusted odds for mortality: 12:00–13:00 (adjusted OR 2.277; 95% CI 1.392–3.725) and 19:00–20:00 (adjusted OR 1.873; CI 1.873; 95% 1.099–3.190).

4. Discussion

4.1. Key results

We found that night-time RRT calls were not associated with higher mortality rates. As a post-hoc generated hypothesis, the two periods with the highest risk of mortality correspond to the times of nursing handover. These results remained even after adjusting for confounding factors related to patients and calls.

4.2. Interpretation and comparison with previous studies

Our results differ from other studies that found that nighttime RRT calls are associated with worse outcomes [11-13].Some characteristics of the hospital and the RRT may explain these differences. In the study by Fernando et al., the RRT comprised an intensivist during the day and a resident physician at night, in addition to the support of a registered nurse and a respiratory therapist [12]. In the study by Singh et al., there was also an intensivist supervising RRT calls only during the day [11]. At our center, the composition of the RRT does not change according to the shift; an intensivist is responsible for answering all calls, 24/7. Mankidy et al. found that the addition of an intensivist-led RRT to a nurse-led RRT significantly reduced the occurrence of cardiac arrest in the hospital [8]. Furthermore, the nurse-to-patient ratio was lower at night in the study by Fernando et al. [12]. In our study, the nurse-to-patient ratio remained the same throughout the 24 h of the day. Thus, less experienced physicians in RRT and a reduction in the nurse-to-patient ratio at night may explain the difference in the results.

Another characteristic that can contribute to worse outcomes is the incidence of activation delays. Several studies have shown an association between delayed RRT activation and worse outcomes [14-17]. A greater delay in nighttime activation was verified in the study by Fernando et al. and was suggested in the study by Chuperk et al. [12,13]. Although the triggers were different between shifts (cardiovascular and respiratory changes were more common causes of nighttime activation, whereas neurological and laboratory changes were more common during the daytime), the incidence of delay in activation was not higher at night in our study. The maturity of the system and maintenance of the nurse-to-patient ratio may have contributed to the lack of a longer delay in nighttime activation.

Regarding the time of activation, we found that the pattern of calls

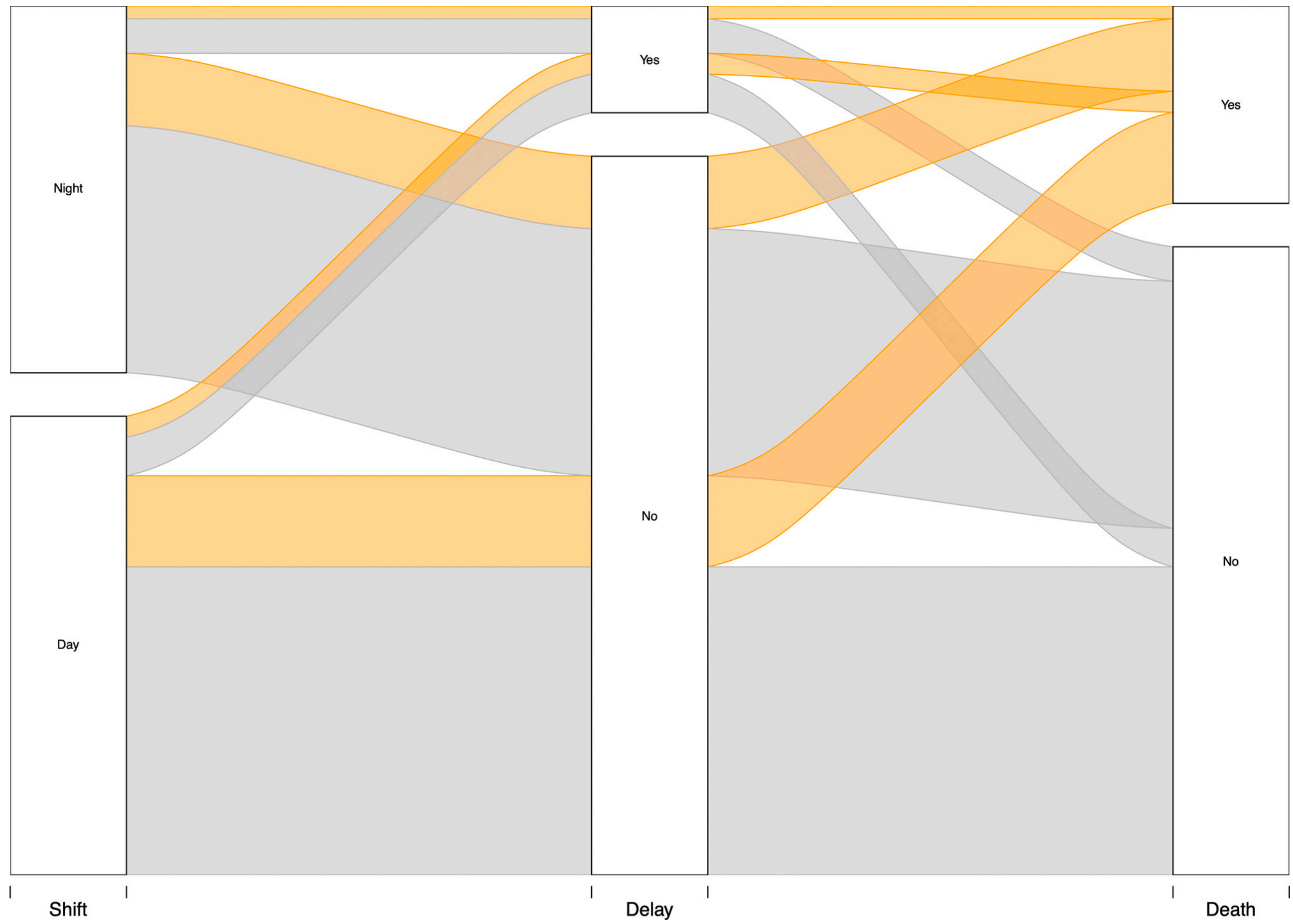

Fig. 2. Trajectory of the patients from activation shift to primary outcome.

was not uniform throughout the 24 h of the day. Activation of the RRT was greater in the early morning and afternoon hours and at the end of the night shift, times that coincided with the routine observation of vital signs and were close to the nursing handover. In addition, we noticed a decrease in the number of calls during the nursing handover. Jones et al. had already shown that the occurrence of calls is higher before nursing handover and after routine observation of vital signs [18]. The heterogeneity in the occurrence of calls is worrisome. Patients are unlikely to experience more frequent clinical deterioration at specific times that coincide with nursing observations or during nursing handovers [18]. The time of nursing handover was associated not only with a decrease in the number of calls but also with higher mortality. We hypothesize that this association may be due to delays in the detection of deterioration around the time of the nursing handover. However, we did not find a higher prevalence of documented delay at these times, which should be explored further in future studies. Although we used the definition of delayed activation that has already been used in other studies, this definition requires documentation of deranged vital signs and may fail to identify delays that occur in some calls. This inverse relationship between RRT "dose" and mortality has been demonstrated in other studies [19,20]. More frequent or automated observation of vital signs can improve RRT activation [13,21]. Contact-free sensors that enable the continuous measurement of heart and respiratory rates and electronic algorithms that include demographics, vital signs, and laboratory tests with machine learning modeling are examples of advances in RRT activation [22].

Table 2
Multivariate regression analysis of in-hospital mortality.

Variable	OR	95% CI
Age	1.017	(1.012–1.022)
Sex, female	0.846	(0.728–0.984)
Medical	2.265	(1.919–2.674)
Cardiovascular trigger	1.235	(1.022–1.494)
Respiratory trigger	1.810	(1.499–2.187)
Neurologic trigger	1.940	(1.538–2.446)
Laboratory trigger	2.696	(2.004–3.626)
Daytime activation	0.991	(0.848–1.158)
Multiple activations	1.439	(1.236–1.676)
Delayed activation	1.570	(1.263–1.952)

4.3. Limitations

Our study has some limitations. This was a single-center study, which limits the generalizability of the results. In addition, analysis of the association between mortality and time of call is limited because we do not have enough data to adjust patients' risk with respect to their baseline severity. Additionally, no structured early warning score was collected; therefore, we were not able to adjust for these variables. Moreover, another limitation of this study is the potential risk of inclusion bias resulting from the exclusion of a substantial portion of patients due to incomplete registration. This exclusion may introduce bias and impact the generalizability of the study findings. Finally, there were limitations inherent to the retrospective design of this study.

5. Conclusion

In conclusion, our study suggests that the timing of RRT calls does not appear to have a significant impact on patient outcomes. The lack of variation in mortality over a 24-h period may be attributed, at least in

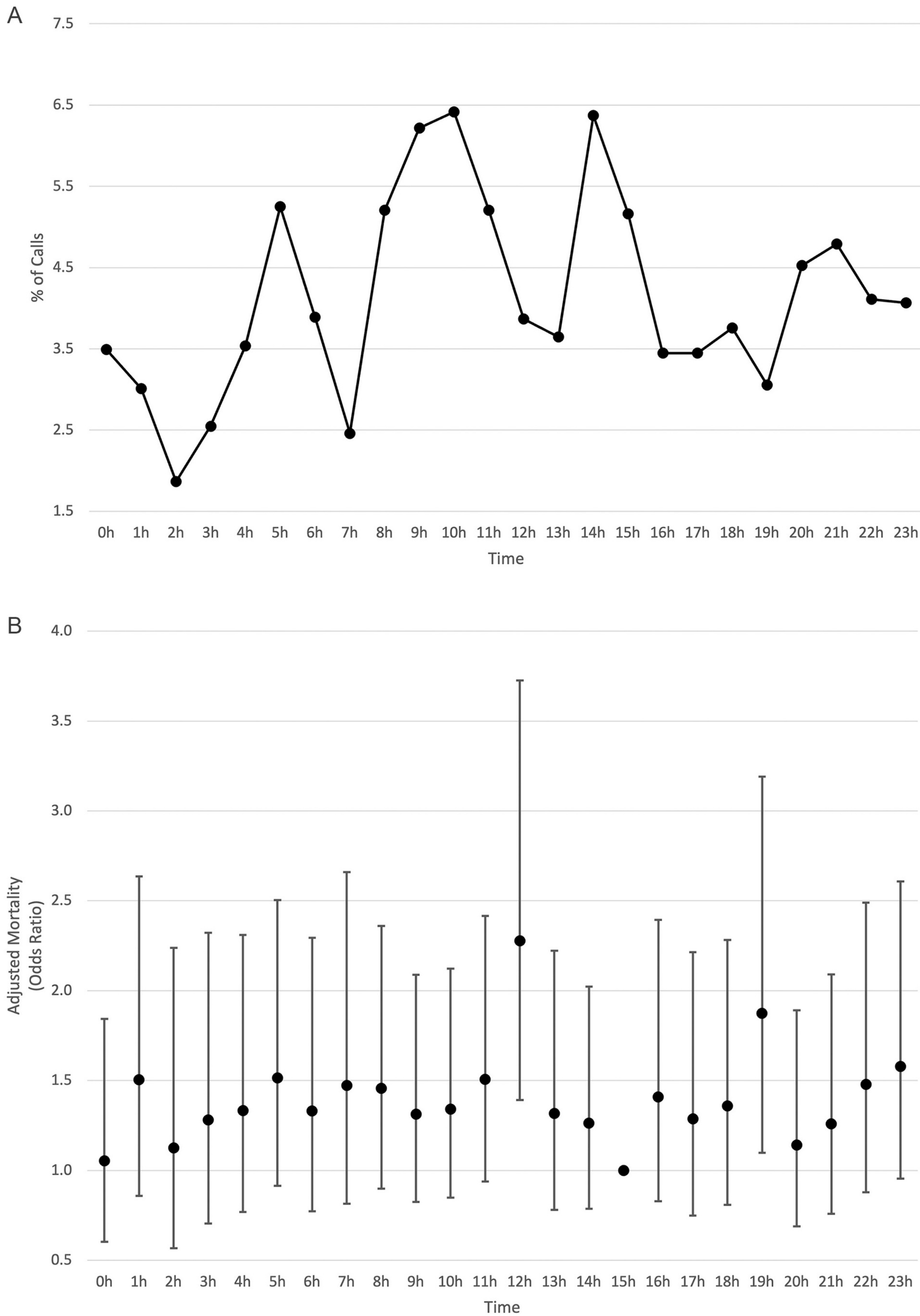

Fig. 3. Percentage of total calls (A) and adjusted in-hospital mortality (B) by time of day of Rapid Response Team activation (using 15:00 as a reference).

part, to the presence of a dedicated intensivist who is available around the clock. Nevertheless, the observed decrease in the number of calls during nursing handovers and the associated increase in mortality highlight the importance of maintaining adequate patient care during these critical times. These findings may inform hospital policies and practices aimed at optimizing RRT utilization and improving patient safety.

Ethics approval and consent to participate

This study protocol was consistent with the ethical principles of the Declaration of Helsinki and was previously approved by the Committee of Research Ethics of Hospital de Clínicas de Porto Alegre. Informed consent was waived.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on request.

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Authors' contributions

MMB, MSL, GM, IGB, JFJ, LAZ, MCP, MVV, MCS, TCDB, WN, DSLN, GBB, JLN, JMD and TCL have made substantial contributions to the conception and design of the study and to acquisition of data; MMB, MSL and TCL performed the analysis and the interpretation of data; all authors read and approved the final manuscript.

Declaration of Competing Interest

None.

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Not applicable.

References

[1] Buist MD, Jarmolowski E, Burton PR, Bernard SA, Waxman BP, Anderson J. Recognising clinical instability in hospital patients before cardiac arrest or unplanned admission to intensive care. A pilot study in a tertiary-care hospital. Med J Aust 1999;171:22–5.

[2] Bell MB, Konrad D, Granath F, Ekbom A, Martling C-R. Prevalence and sensitivity of MET-criteria in a Scandinavian university hospital. Resuscitation 2006;70:66–73.

[3] Franklin C, Mathew J. Developing strategies to prevent inhospital cardiac arrest: analyzing responses of physicians and nurses in the hours before the event. Crit Care Med 1994;22:244–7.

[4] Andersen LW, Kim WY, Chase M, Berg KM, Mortensen SJ, Moskowitz A, et al. The prevalence and significance of abnormal vital signs prior to in-hospital cardiac arrest. Resuscitation 2016;98:112–7.

[5] Daffurn K, Lee A, Hillman KM, Bishop GF, Bauman A. Do nurses know when to summon emergency assistance? Intensive Crit Care Nurs 1994;10:115–20.

[6] Priestley G, Watson W, Rashidian A, Mozley C, Russell D, Wilson J, et al. Introducing critical care outreach: a ward-randomised trial of phased introduction in a general hospital. Intensive Care Med 2004:30. https://doi.org/10.1007/s00134-004-2268-7.

[7] De Jong A, Jung B, Daurat A, Chanques G, Mahul M, Monnin M, et al. Effect of rapid response systems on hospital mortality: a systematic review and meta-analysis. Intensive Care Med 2016;42:615–7.

[8] Mankidy B, Howard C, Morgan CK, Valluri KA, Giacomino B, Marfil E, et al. Reduction of in-hospital cardiac arrest with sequential deployment of rapid response team and medical emergency team to the emergency department and acute care wards. PloS One 2020;15:e0241816.

[9] Tirkkonen J, Skrifvars MB, Tamminen T, Parr MJA, Hillman K, Efendijev I, et al. Afferent limb failure revisited - a retrospective, international, multicentre, cohort study of delayed rapid response team calls. Resuscitation 2020;156:6–14.

[10] Sundararajan K, Flabouris A, Thompson C. Diurnal variation in the performance of rapid response systems: the role of critical care services—a review article. J Intensive Care 2016:4. https://doi.org/10.1186/s40560-016-0136-5.

[11] Singh MY, Vegunta R, Karpe K, Rai S. Does the time of solitary rapid response team call affect patient outcome? Indian J Crit Care Med 2020;24:38–43.

[12] Fernando SM, Reardon PM, Bagshaw SM, Scales DC, Murphy K, Shen J, et al. Impact of nighttime rapid response team activation on outcomes of hospitalized patients with acute deterioration. Crit Care 2018;22:67.

[13] Churpek MM, Edelson DP, Lee JY, Carey K, Snyder A. American Heart Association's get with the guidelines-resuscitation investigators. Association between survival and time of day for rapid response team calls in a national registry. Crit Care Med 2017;45:1677–82.

[14] Barwise A, Thongprayoon C, Gajic O, Jensen J, Herasevich V, Pickering BW. Delayed rapid response team activation is associated with increased hospital mortality, morbidity, and length of stay in a tertiary care institution. Crit Care Med 2016;44:54–63.

[15] Boniatti MM, Azzolini N, Viana MV, Ribeiro BSP, Coelho RS, Castilho RK, et al. Delayed medical emergency team calls and associated outcomes. Crit Care Med 2014;42:26–30.

[16] Reardon PM, Fernando SM, Murphy K, Rosenberg E, Kyeremanteng K. Factors associated with delayed rapid response team activation. J Crit Care 2018;46:73–8.

[17] Chen J, Bellomo R, Flabouris A, Hillman K, Assareh H, Ou L. Delayed emergency team calls and associated hospital mortality: a multicenter study. Crit Care Med 2015;43:2059–65.

[18] Jones D, Bates S, Warrillow S, Opdam H, Goldsmith D, Gutteridge G, et al. Circadian pattern of activation of the medical emergency team in a teaching hospital. Crit Care 2005;9:R303–6.

[19] Jones D, Bellomo R, DeVita MA. Effectiveness of the medical emergency team: the importance of dose. Crit Care 2009;13:313.

[20] Jones D, Bellomo R, Bates S, Warrillow S, Goldsmith D, Hart G, et al. Patient monitoring and the timing of cardiac arrests and medical emergency team calls in a teaching hospital. Intensive Care Med 2006;32:1352–6.

[21] Danesh V, Neff D, Jones TL, Aroian K, Unruh L, Andrews D, et al. Can proactive rapid response team rounding improve surveillance and reduce unplanned escalations in care? A controlled before and after study. Int J Nurs Stud 2019;91:128–33.

[22] Churpek MM, Yuen TC, Winslow C, Meltzer DO, Kattan MW, Edelson DP. Multicenter comparison of machine learning methods and conventional regression for predicting clinical deterioration on the wards. Crit Care Med 2016;44:368–74.