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НОВЫЙ ДЕНЬ В МЕДИЦИНЕ
NEW DAY IN MEDICINE

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INFLUENCE OF BURN TOXEMIA ON RESPIRATORY FUNCTION AS ASSESSED BY CIRCADIAN RHYTHMS OF RESPIRATORY RATE AND PERIPHERAL OXYGEN SATURATION IN CHILDREN AGED 7-18 YEARS

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✓ ***Resume***

This study evaluated respiratory adaptation during the toxemia phase of severe burn disease using circadian characteristics of respiratory rate (RR) and peripheral oxygen saturation (SpO_2) in 26 children aged 7.1–18 years. Patients were stratified into three groups according to intensive care unit (ICU) stay: Group 1, n=12 (≤10 days); Group 2, n=7 (11–20 days); and Group 3, n=7 (>21 days). Hourly RR and SpO_2 were analyzed with assessment of mesor, amplitude, acrophase shifts, and rhythm inversion. On admission, the RR mesor was 21.3±0.8, 20.7±0.6, and 25.0±3.8 breaths/min in Groups 1, 2, and 3, respectively. The mean RR mesor during the observation period was highest in Group 3 (23.7±0.7 breaths/min). Mean SpO_2 remained high across groups (97.9±0.2%), but the first-day amplitude of SpO_2 fluctuations was greatest in Group 3 (2.3%). The longest inversion of the SpO_2 circadian rhythm was also observed in Group 3 (41% of the observation period). The RR–SpO_2 relationship was most consistently positive in Group 1, less stable in Group 2, and not significant in Group 3. These findings suggest that increasing burn severity and longer ICU treatment are associated with greater circadian disorganization of respiratory regulation and reduced coupling between ventilatory response and oxygenation.

Keywords: severe burns, children, burn toxemia, respiratory rate, peripheral oxygen saturation, circadian rhythm, acrophase, intensive care.

7-18 YOSHLI BOLALARDA KUYISH TOKSEMIYASINING NAFAS FAOLIYATIGA TA’SIRI: NAFAS OLISH TEZLIGI VA PERIFERIK KISLOROD SATURATSIYASINING SIRKADIYALIK RITMLARI ASOSIDA BAHOLASH

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✓ ***Rezyume***

Ushbu tadqiqotda og‘ir kuyish kasalligining toksemiya davrida nafas olish tezligi va periferik kislorod saturatsiyasining sirkadiyalik xususiyatlari asosida respirator moslashuv baholandi. Tadqiqotga 7,1 dan 18 yoshgacha bo‘lgan 26 nafar bola kiritildi. Bemorlar intensiv terapiya bo‘limida davolanish davomiyligiga ko‘ra uch guruhga ajratildi. Birinchi guruhga 10 kungacha davolangan 12 nafar bola, ikkinchi guruhga 11 dan 20 kungacha davolangan 7 nafar bola, uchinchi guruhga esa 21 kundan ortiq davolangan 7 nafar bola kiritildi. Nafas olish tezligi va periferik kislorod saturatsiyasi ko‘rsatkichlari soatbay monitoring qilinib, sirkadiyalik ritmning mezori, amplitudasi, akrofaza siljishlari va ritm inversiyasi tahlil qilindi. Bemorlar shifoxonaga qabul qilingan vaqtda nafas olish tezligining sirkadiyalik mezori birinchi, ikkinchi va uchinchi

guruhlarda mos ravishda 21,3±0,8; 20,7±0,6 va 25,0±3,8 nafas/minutni tashkil etdi. Kuzatuv davri davomida nafas olish tezligining o‘rtacha sirkadiyalik mezori uchinchi guruhda eng yuqori bo‘lib, 23,7±0,7 nafas/minutni tashkil etdi.

Periferik kislorod saturatsiyasining o‘rtacha ko‘rsatkichi barcha guruhlarda yuqori darajada saqlanib, 97,9±0,2 foizni tashkil etdi. Biroq birinchi sutkada periferik kislorod saturatsiyasi tebranishlarining eng katta amplitudasi uchinchi guruhda kuzatilib, 2,3 foizni tashkil etdi. Periferik kislorod saturatsiyasi sirkadiyalik ritmining eng uzoq davom etgan inversiyasi ham uchinchi guruhda aniqlanib, kuzatuv davrining 41 foizini tashkil etdi. Nafas olish tezligi bilan periferik kislorod saturatsiyasi o‘rtasidagi bog‘liqlik birinchi guruhda eng barqaror musbat xarakterga ega bo‘ldi. Ikkinchi guruhda bu bog‘liqlik kamroq barqaror bo‘ldi, uchinchi guruhda esa statistik jihatdan ahamiyatli bog‘liqlik aniqlanmadi. Olingan natijalar kuyishning og‘irlik darajasi va intensiv terapiya bo‘limida davolanish davomiyligi ortishi nafas faoliyatining sirkadiyalik boshqaruvi yanada chuqurroq buzilishi hamda nafas olish javobi bilan oksigenatsiya o‘rtasidagi uyg‘unlikning pasayishi bilan bog‘liq ekanligini ko‘rsatadi.

Kalit so‘zlar: og‘ir kuyishlar, bolalar, kuyish toksemiyasi, nafas olish tezligi, periferik kislorod saturatsiyasi, sirkadiyalik ritm, akrofaza, intensiv terapiya.

ВЛИЯНИЕ ОЖОГОВОЙ ТОКСЕМИИ НА ФУНКЦИЮ ДЫХАНИЯ У ДЕТЕЙ 7-18 ЛЕТ: ОЦЕНКА ПО ЦИРКАДНЫМ РИТМАМ ЧАСТОТЫ ДЫХАНИЯ И ПЕРИФЕРИЧЕСКОЙ САТУРАЦИИ КИСЛОРОДА

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✓ ***Резюме***

В данном исследовании оценивали респираторную адаптацию в период токсемии тяжёлой ожоговой болезни на основании циркадных характеристик частоты дыхания и периферической сатурации кислорода. В исследование включены 26 детей в возрасте от 7,1 до 18 лет. Пациенты были разделены на три группы в зависимости от продолжительности лечения в отделении интенсивной терапии. В первую группу вошли 12 детей, лечившихся до 10 суток, во вторую группу 7 детей, лечившихся от 11 до 20 суток, в третью группу 7 детей, находившихся на лечении более 21 суток. Показатели частоты дыхания и периферической сатурации кислорода регистрировали при почасовом мониторинге с последующим анализом мезора, амплитуды, сдвигов акрофазы и инверсии циркадного ритма. При поступлении мезор циркадного ритма частоты дыхания в первой, второй и третьей группах составил соответственно 21,3±0,8; 20,7±0,6 и 25,0±3,8 дыхательных движений в минуту. В течение периода наблюдения средний мезор частоты дыхания был наиболее высоким в третьей группе и составил 23,7±0,7 дыхательных движений в минуту.

Среднее значение периферической сатурации кислорода во всех группах сохранялось на высоком уровне и составило 97,9±0,2%. При этом в первые сутки наибольшая амплитуда колебаний периферической сатурации кислорода наблюдалась в третьей группе и составила 2,3%. Наиболее продолжительная инверсия циркадного ритма периферической сатурации кислорода также была выявлена в третьей группе и занимала 41% периода наблюдения. В первой группе взаимосвязь между частотой дыхания и периферической сатурацией кислорода имела наиболее устойчивый положительный характер. Во второй группе эта взаимосвязь была менее стабильной, а в третьей группе статистически значимая связь не выявлена. Полученные результаты показывают, что увеличение тяжести ожогового поражения и продолжительности лечения в отделении интенсивной терапии сопровождается более выраженным нарушением циркадной регуляции дыхательной функции и снижением согласованности между вентиляционным ответом и оксигенацией.

Ключевые слова: тяжёлые ожоги, дети, ожоговая токсемия, частота дыхания, периферическая сатурация кислорода, циркадный ритм, акрофаза, интенсивная терапия.

Relevance

Severe burns in children produce systemic inflammatory, cardiovascular, respiratory, and metabolic disturbances that may compromise pulmonary function even in the absence of direct inhalation injury. Contemporary pediatric burn care therefore emphasizes close monitoring of airway status, oxygenation, ventilation, and circulatory stability [1]. Respiratory failure and acute respiratory distress syndrome (ARDS) in burn patients may develop through inflammatory lung injury, infection, capillary leak, fluid shifts, and, when present, inhalation injury [2,3].

Severe burn injury also induces a sustained hypermetabolic stress response characterized by increased whole-body oxygen consumption, increased energy expenditure, and increased metabolic substrate turnover [4,5]. These changes increase cardiopulmonary demand and may alter the relationship between respiratory rate and oxygenation during the acute and toxemia phases of burn disease. In children, respiratory morbidity may persist even after cutaneous burns without documented smoke inhalation, supporting the clinical importance of systematic respiratory surveillance [6]. Critical illness and the ICU environment can disrupt endogenous circadian organization, including rhythms related to autonomic, cardiovascular, respiratory, and metabolic regulation [7]. Because conventional spot measurements may fail to capture time-dependent physiological instability, prolonged monitoring with phase analysis may provide additional information about compensatory respiratory responses. Accordingly, assessment of the circadian dynamics of RR and SpO_2 in children with severe burns is clinically relevant for identifying altered respiratory adaptation and periods of reduced compensatory efficiency.

To assess the influence of burn toxemia on respiratory function using circadian characteristics of respiratory rate and peripheral oxygen saturation in children aged 7–18 years with severe thermal burns.

Materials and methods

The study was based on hourly monitoring of respiratory rate (RR) and peripheral oxygen saturation (SpO_2) by pulse oximetry in children admitted to the Republican Scientific Center for Emergency Medical Aid with severe thermal burns. Circadian phase analysis was performed in 26 children aged 7.1–18 years during the toxemia period. Patients were divided into three groups according to the duration of intensive care, which reflected the clinical severity and complexity of burn disease: Group 1 included 12 children treated in the ICU for up to 10 days (mean 7.3±1.1 days), Group 2 included 7 children treated for 11–20 days (mean 12.7±1.1 days), and Group 3 included 7 children treated for more than 21 days (mean 28.8±4.8 days).

Table 1. Patient characteristics

Group	Age, years	Boys	Girls	ICU stay, days	Burn area 2–3A, %	Burn area 3B, %	IF, units
Group 1	11.4±3.2	10	2	7.3±1.1	41±11	6.6±6	57±11
Group 2	15.0±2.0	6	1	12.7±1.1*	55.1±14.4	4.8±3.5	86.3±15.7*
Group 3	9.7±1.5	4	3	28.8±4.8*	25.8±11.4	22.5±6.6*	95.8±19.1*

*Significant versus Group 1; † significant versus Group 2, as reported in the source dataset.

Group 1 included 10 boys and 2 girls, Group 2 included 6 boys and 1 girl, and Group 3 included 4 boys and 3 girls. The mean ages were 11.4±3.2, 15.0±2.0, and 9.7±1.5 years, respectively. In Group 3, the proportion of deep 3B burns was substantially greater (22.5±6.6%) than in Groups 1 and 2 (6.6±6.0% and 4.8±3.5%, respectively), and the injury severity index was highest (95.8±19.1 units). The analyzed circadian parameters included the daily mesor, amplitude of fluctuations, acrophase shifts, and rhythm inversion. Statistical significance markers reported in the source dataset were interpreted at $p<0.05$; however, the exact statistical tests were not specified in the provided manuscript and should be documented in the final submission.

Results and discussions

On the day of admission, the RR mesor was 21.3±0.8 breaths/min in Group 1, 20.7±0.6 breaths/min in Group 2, and 25.0±3.8 breaths/min in Group 3. No clear departure from the expected age-related range was reported on day 1, although Group 3 showed the highest RR value (tab. 2). During follow-up, RR increased by approximately 8% on days 7 and 9 in Group 1 and on days 9 and 11 in Group 2 ($p<0.05$ versus day 1). These changes are more appropriately interpreted as increased ventilatory demand during burn toxemia rather than as proof of acute respiratory failure, because arterial blood gas data, PaO_2/FiO_2 ratio, and formal respiratory-failure criteria were not provided.

Table 2. Dynamics of the mesor of the circadian rhythm of respiratory rate during burn toxemia

Day	Group 1	Group 2	Group 3
1	21.3±0.8	20.7±0.6	25.0±3.8
2	21.2±0.3	21.3±0.4	22.4±0.4
3	21.1±0.2	20.7±0.3	22.8±0.3
4	22.1±0.4	20.8±0.3	23.3±0.4
5	22.3±0.3	21.1±0.4	23.2±0.4
6	22.3±0.2	21.1±0.5	23.0±0.3
7	23.0±0.7*	21.0±0.4	23.6±0.3
8	22.1±0.9	21.3±0.6	23.9±0.4
9	23.8±0.7*	22.4±0.5*	23.0±0.5
10		21.8±0.5	23.2±0.3
11		22.3±0.5*	23.2±0.6
12		22.1±0.7	22.4±0.3
13			24.4±0.4
14			24.0±0.5
15			24.2±0.4
16			24.9±0.5
17			24.0±0.5
18			24.1±0.5
19			23.9±0.7
20			24.3±0.4
21			24.6±0.5
22			24.8±0.5
23			24.3±0.9
24			22.8±0.6
25			22.8±0.9

* p<0.05 versus day 1, as reported in the source manuscript.

Across the observation period, the mean RR mesor was highest in Group 3 (23.7±0.7 breaths/min), compared with 22.1±0.6 breaths/min in Group 1 and 21.4±0.5 breaths/min in Group 2. The maximal first-day amplitude of RR fluctuations was also greatest in Group 3 (4 breaths/min), versus 2.3 breaths/min in Group 2 and 1.3 breaths/min in Group 1. Thus, the group with the longest ICU course and the largest proportion of deep burns demonstrated the greatest temporal variability in respiratory rate.

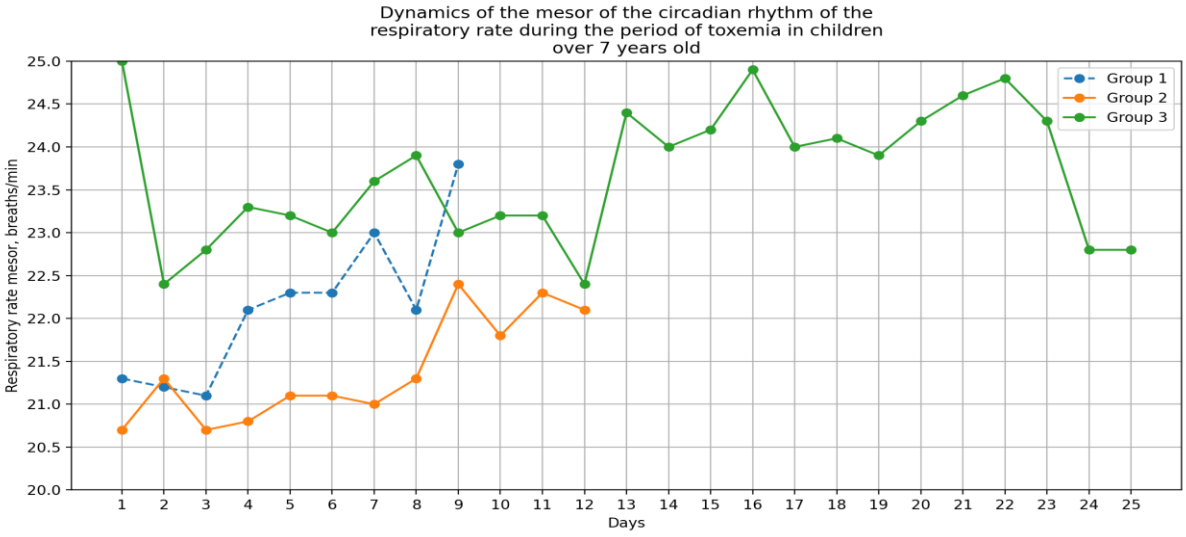


Figure 1. Dynamics of the mesor of the circadian rhythm of respiratory rate during the toxemia period in children aged over 7 years

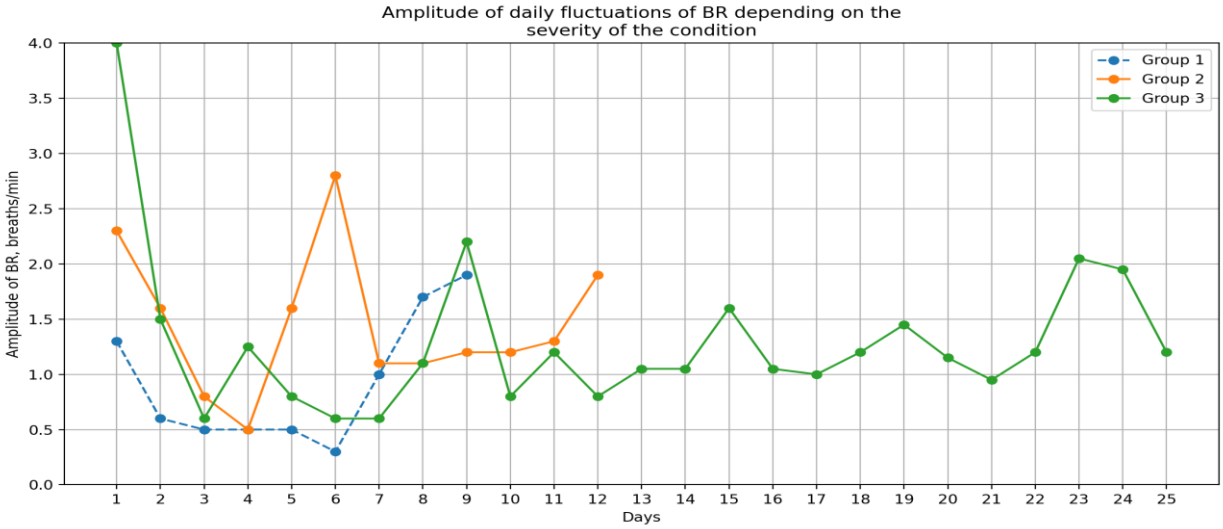


Figure 2. Amplitude of daily respiratory-rate fluctuations according to clinical severity

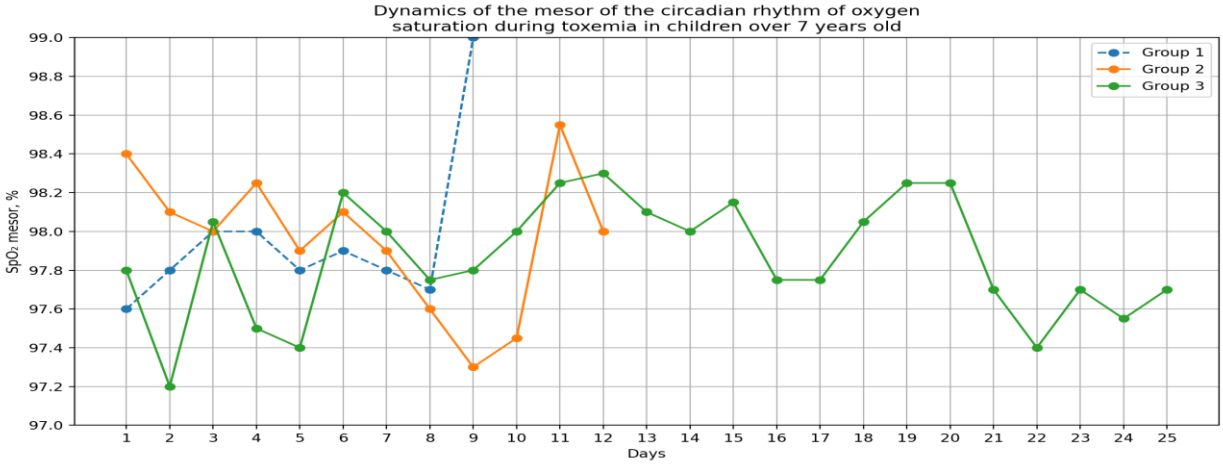


Figure 3. Dynamics of the mesor of the circadian rhythm of peripheral oxygen saturation during toxemia

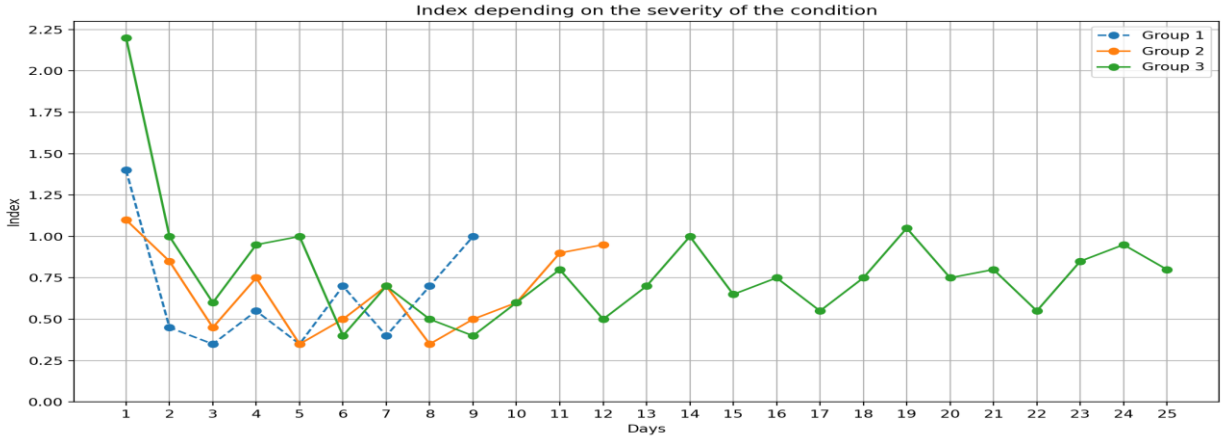


Figure 4. Amplitude of daily peripheral oxygen-saturation fluctuations according to clinical severity

SpO_2 remained generally preserved. On day 1, the daily mesor ranged from 97.6% in Group 1 to 98.3% in Group 2, and the mean value across the toxemia period was 97.9±0.2%. Despite these relatively normal mean values, day-to-day and within-day variability differed according to severity. On the first day, the amplitude of

SpO_2 fluctuations was 1.4% in Group 1, 1.2% in Group 2, and 2.3% in Group 3. This suggests that circadian variability may reveal physiological instability that is not evident from the mean SpO_2 value alone.

Phase analysis showed more pronounced circadian disorganization in children with a longer ICU stay. In Group 3, grade 2 and grade 3 shifts in the RR acrophase accounted for 54% and 34% of the intensive-care period, respectively. In Group 1, a moderate daytime acrophase shift predominated (44%). For SpO_2, daytime acrophase displacement predominated in Groups 1 and 2 (55% and 50%, respectively), whereas the longest inversion of the SpO_2 circadian rhythm was observed in Group 3 and occupied 41% of the observation period.

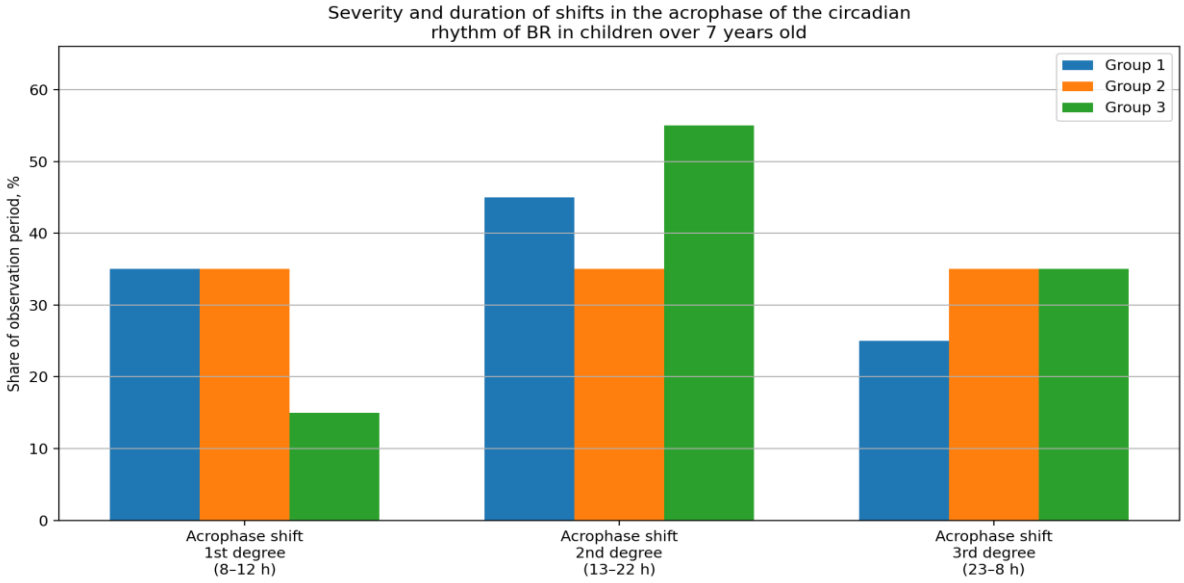


Figure 5. Severity and duration of respiratory-rate acrophase shifts in children aged over 7 years

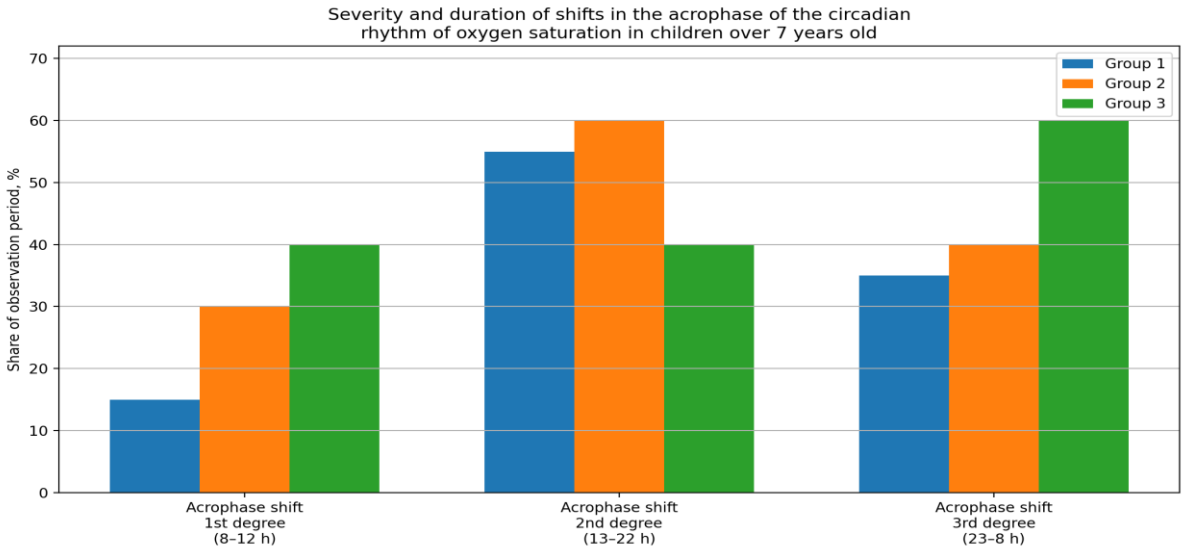


Figure 6. Severity and duration of peripheral oxygen-saturation acrophase shifts in children aged over 7 years

The hourly relationship between RR and SpO_2 also differed among groups. In Group 1, positive RR–SpO_2 correlations were observed during 11 of 24 hourly intervals, suggesting that an increase in respiratory rate was frequently accompanied by preserved or improved oxygenation. In Group 2, this compensatory pattern was identified only at 22:00, while inverse correlations were observed at 23:00 (r=-0.60) and 03:00 (r=-0.68). In Group 3, correlations between RR mesor and SpO_2 were not significant. Given that mean SpO_2 remained close to 98%, these findings should be interpreted as reduced coupling between ventilatory response and oxygenation rather than direct evidence of hypoxemic respiratory failure.

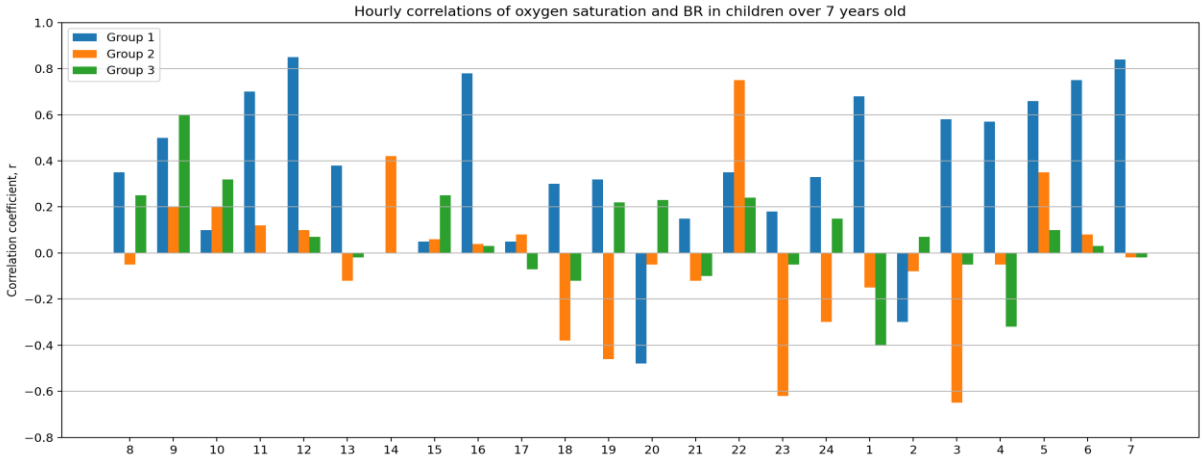


Figure 7. Hourly correlations between peripheral oxygen saturation and respiratory rate in children aged over 7 years

The findings are consistent with modern concepts of severe burn physiology. Systemic inflammation and capillary permeability can impair pulmonary function and contribute to ARDS even without direct airway injury [2,3]. At the same time, burn-induced hypermetabolism increases oxygen consumption and metabolic demand [4,5]. In critically ill patients, circadian organization may be additionally disrupted by disease severity and the ICU environment [7]. The present data therefore support the use of prolonged respiratory monitoring as a complementary tool for characterizing compensatory reserve in pediatric burn disease. However, the interpretation must account for the small sample size, unequal age distribution among groups, and the fact that grouping by ICU duration introduces potential severity and outcome-related confounding.

Conclusion

In children aged 7–18 years with severe burns, greater clinical severity and prolonged ICU treatment were associated with more pronounced circadian disturbances of respiratory rate and peripheral oxygen saturation. Group 3 demonstrated the highest mean RR mesor, the largest first-day RR and SpO_2 fluctuation amplitudes, and the longest SpO_2 rhythm inversion. The progressive loss of a consistent positive RR–SpO_2 relationship from Group 1 to Group 3 suggests reduced efficiency of respiratory compensation as burn disease becomes more severe. Circadian analysis of RR and SpO_2 may therefore complement conventional monitoring by identifying periods of increased physiological instability, although these findings require confirmation in larger studies with age adjustment, explicit statistical methodology, blood gas analysis, and standardized definitions of respiratory dysfunction.

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