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SHORT COMMUNICATION

Unplanned and medical admissions to pediatric intensive care units significantly decreased during COVID-19 outbreak in Northern Italy

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Abstract

Northern Italy has been the first European area affected by the COVID-19 pandemic and related social restrictive measures. We sought to evaluate the impact of the COVID-19 outbreak on PICU admissions in Northern Italy, using data from the Italian Network of Pediatric Intensive Care Units Registry. We included all patients admitted to 4 PICUs from 8-weeks-before to 8-weeks-after February 24th, 2020, and those admitted in the same period in 2019. Incidence rate ratios (IRR) evaluating incidence rate differences between pre- and post-COVID-19 periods in 2020 (IRR-1), as well as between the post-COVID-19-period with the same period in 2019 (IRR-2), were computed using zero-inflated negative binomial or Poisson regression modeling. A total of 1001 admissions were included. The number of PICU admissions significantly decreased during the COVID-19 outbreak compared to pre-COVID-19 and compared to the same period in 2020 (IRR-1 0.63 [95%CI 0.50–0.79]; IRR-2 0.70 [CI 0.57–0.91]). Unplanned and medical admissions significantly decreased (IRR-1 0.60 [CI 0.46–0.70]; IRR-2 0.67 [CI 0.51–0.89]; and IRR-1 0.52, [CI 0.40–0.67]; IRR-2 0.77 [CI 0.58–1.00], respectively). Intra-hospital, planned (potentially delayed by at least 12 h), and surgical admissions did not significantly change. Patients admitted for respiratory failure significantly decreased (IRR-1 0.55 [CI 0.37–0.77]; IRR-2 0.48 [CI 0.33–0.69]).

Francesca Sperotto and Andrea Wolfler contributed equally to this work.

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Conclusions: Unplanned and medical PICU admissions significantly decreased during COVID-19 outbreak, especially those for respiratory failure.

What is Known:
- *Northern Italy has been the first European area affected by the COVID-19 pandemic.*
- *Although children are relatively spared from the severe COVID-19 disease, the pediatric care system has been affected by social restrictive measures, with a reported 73–88% reduction in pediatric emergency department admissions.*

What is New:
- *Unplanned and medical PICU admissions significantly decreased during the COVID-19 outbreak compared to pre-COVID-19 and to the same period in 2019, especially those for respiratory failure. Further studies are needed to identify associated factors and new prevention strategies.*

Keywords Pediatric critical care · Intensive care · Pandemic · COVID-19 · Public health · Pediatrics · Children

Abbreviations

COVID-19	Coronavirus disease 2019
CI	Confidence interval
IQR	Interquartile ranges
IRR	Incidence rate ratio
PICU	Pediatric Intensive Care Unit
PIM3	Pediatric Index of Mortality Score 3
TIPNet	Italian Network of Pediatric Intensive Care Units

Introduction

Northern Italy has been the first European area in which the COVID-19 pandemic has spread. Although the number of pediatric patients affected by COVID-19 and the severity of symptoms is limited compared to adults [1–4], undirected changes affecting the pediatric care system have been described since the beginning of the outbreak. A recent study reported a 73–88% reduction in pediatric emergency department admissions after the implementation of lockdown measures, compared to the same period in 2018–2019 [5]. Variations in rates and types of admission to the pediatric intensive care units (PICUs) in this period have not yet been investigated. Here, we sought to evaluate the impact of the COVID-19 outbreak and lockdown measures on rates and types of PICU admissions in Northern Italy. To adequately contextualize this analysis, we also evaluated the overall pediatric mortality rate in the same periods and geographic area.

Material and methods

Data source and ethics approval

PICU admission data were extracted from the Italian Network of Pediatric Intensive Care Units (TIPNet) Registry. TIPNet is a Research Network involving 18 Italian PICUs. Ethics Committees of each Center approved the use of the Registry for no-profit research purposes, with a waiver for informed consent due to the observational nature and anonymity of data. Data are prospectively inserted each day of PICU stay into an electronic standardized sheet (REDCap-platform, REDCap, TN, USA). Data are anonymized at the moment of data extraction. Finally, overall mortality data were extracted from the Italian National Institute of Statistics (ISTAT) public repository. All investigations were carried out in accordance with the Declaration of Helsinki.

Study population and data collection

We included all patients admitted to 4 PICUs in Northern Italy (Padova, Verona, Milano, Alessandria) in the period included between 8-weeks-before and 8-weeks-after the first administrative lockdown decree (24th February 2020) [6], and patients admitted in the same period in 2019. All patients admitted to the PICUs were registered. All centers maintained their role of reference for PICU admissions during the COVID-19 outbreak, and no transfer to other centers was registered. Children's Hospital Vittore Buzzi admitted also adult patients during the outbreak, but pediatric admissions were never readdressed to other centers. The following variables were extracted: age, gender, center of admission, date of admission, type of admission (medical/surgical/traumas, planned/unplanned, intra-hospital/extra-hospital), diagnosis of admission, Pediatric Index of Mortality Score 3 (PIM3) [7], presence of comorbidities, and diagnosis at discharge. Planned admissions were defined as admissions that may be delayed by at least 12 h.

For the overall mortality rate analysis, we included all data on residence and mortality regarding the same municipalities involved in the PICU admission analysis.

Statistical analysis

Descriptive data were reported in terms of absolute frequencies for categorical variables, and in terms of medians and interquartile ranges (IQR) for continuous variables. Age and PIM3 values were compared between the 2019 and 2020 cohorts using the Wilcoxon-rank sum test. Incidence rate ratios (IRRs) evaluating incidence rate differences between pre- and post-COVID-19 periods in 2020 (IRR-1), as well as between the post-COVID-19-period with the same period in 2019 (IRR-2), and their 95% confidence intervals were computed using zero-inflated negative binomial or Poisson modeling according to the data distribution, with tuning parameters estimated from data [8, 9]. The zero-inflated method was preferred to account for both possible inflation of categories with no observation and overdispersion in counts data. Nighty-five percent confidence intervals (CIs) were computed using a bootstrapping technique. Finally, the daily mortality rates of the 16-week period in 2019 and of the same period in 2020 were computed as ratios between the daily number of deaths and the population at risk in the same areas. The IRR and 95% CI evaluating the difference in mortality rates between 2019 and 2020 was then computed using a Poisson regression modeling. All statistical analyses were performed using the R statistics statistical software (version 3.6.2., R Core Team, R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was set at a two-sided p value < 0.05.

Results

Study population

Overall, 1001 patients were included. Over the course of the 2020 16-week period, a total of 443 patients were admitted to the 4 PICUs (9 [2%] affected by COVID-19). In the same period in 2019, 558 patients were admitted to the same centers. The median age was 0.9 years in the 2019 cohort (interquartile range [IQR] 0.1–5.0), and 1.2 years (IQR 0.2–5.9) in the 2020 cohort (p = 0.103). The PIM3 score was similar in the two cohorts (0.009 [IQR 0.004–0.032] vs 0.008 [IQR 0.005, 0.035], p = 0.94).

Frequency of PICU admissions and incidence rate ratios

Characteristics, frequencies of PICU admissions, and estimated IRRs are shown in Table 1. Overall, the number of PICU admissions significantly decreased by 37% compared to pre-COVID-19 (IRR-1 0.63 [CI 0.50–0.79]) and by 30% compared to 2019 (IRR-2 0.70 [CI 0.57–0.91]) (Fig. 1). PICU admissions decreased especially among patients < 1 year (IRR-1 0.64 [CI 0.47–0.91]), but this is not significant when compared to 2019. Unplanned admissions decreased by 40% compared to pre-COVID-19 (IRR-1 0.60 [CI 0.46–0.70]) and by 37% compared to 2019 (IRR-2 0.67 [CI 0.51–0.89]). Medical admissions decreased by 50% compared to pre-COVID-19 (IRR-1 0.52, [CI 0.40–0.67]) and by 23% compared to 2019 (IRR-2 0.77 [CI 0.58–1.00]. Extra-hospital admissions decreased by 50% compared to pre-COVID-19 (IRR-1 0.50 [CI 0.37–0.65]) and by 30% compared to 2019 (IRR-1 0.70 [CI 0.52–0.97]). Intra-hospital, planned, and surgical admissions did not significantly change. Patients admitted for respiratory failures decreased by 45% compared to pre-COVID-19 (IRR-1 0.55 [CI 0.37–0.77]) and by 52% compared to 2019 (IRR-2 0.48 [CI 0.33–0.69]). Other admission or discharge diagnoses did not significantly differ. Patients with comorbid conditions were admitted significantly less frequently during COVID-19 outbreak compared to the pre-COVID-19 period (IRR 0.73 [0.56–0.96]), but did not significantly differ from 2019.

Overall mortality rate analysis

The overall pediatric mortality rate computed for the same geographic area in the 2020 16-week study period did not significantly differ from 2019 (IRR 1.23 [CI 0.60–2.53], Supplemental Figure 1).

Discussion

With this study, we have shown that unplanned and medical PICU admissions significantly decreased during the COVID-19 outbreak compared to pre-COVID-19 and to 2019. Particularly, PICU admissions for respiratory failure significantly decreased compared to pre-COVID-19 and to 2019.

A decrease in PICU admissions could have been theoretically expected due to the reorganization of elective-care within medical and surgical departments. However, our findings showed that planned admissions did not significantly change. This can be explained by the fact that "planned" PICU activity cannot be considered as a direct synonym of "elective," since often involves critically patients whose admission can be delayed only by few hours or days (e.g., patients needed monitoring during infusions or procedures, vascular lines placements, etc.). Additionally, even if a large number of surgeries were postponed during the COVID-19-outbreak worldwide, it is also true that urgent interventions were not delayed, and those interventions usually represent the most significant determinant in the number of surgical PICU admissions.

Conversely, we found that unplanned medical admissions significantly decreased. Prevention of PICU admissions—i.e., reducing the number of patients who present with critical and life-threatening conditions—

Table 1 Characteristics and frequency of admissions to pediatric intensive care units, and estimates of incidence rate ratios (IRR)

Variable	IRR-1 (pre- vs post 2020)	95% confidence interval	IRR-2 (post 2019 vs post 2020)	95% confidence interval	2019			2020		
					N, pre-Feb 24	*N*, post-Feb 24	*N*, tot 2019	*N*, pre-Feb 24	*N*, post-Feb 24	*N*, tot 2020
Admissions, overall	0.63	0.50–0.79	0.70	0.57–0.91	299	259	558	277	166	443
Gender										
Female	0.71	0.52–0.98	0.79	0.57–1.08	134	110	244	115	62	177
Male	0.69	0.53–0.90	0.83	0.63–1.11	165	149	314	162	104	266
Age										
0–1 year	0.65	0.47–0.91	0.90	0.64–1.24	145	94	239	139	65	204
1–3 years	0.71	0.41–1.17	0.80	0.47–1.31	50	45	95	46	24	70
3–6 years	0.97	0.55–1.65	0.86	0.51–1.43	29	43	72	24	22	46
> 6 years	0.80	0.54–1.18	0.80	0.55–1.15	61	70	131	58	42	100
Type of admission										
Extra-hospital	0.50	0.37–0.65	0.70	0.52–0.97	190	130	320	175	77	252
Intra-hospital, ward	0.80	0.52–1.21	1.01	0.66–1.57	49	44	93	49	31	80
Intra-hospital, surgery	1.02	0.69–1.62	0.85	0.60–1.24	49	72	121	45	49	94
Planned	0.86	0.55–1.32	0.93	0.60–1.36	56	73	129	75	45	120
Unplanned	0.60	0.46–0.78	0.67	0.51–0.89	225	170	395	184	99	283
Diagnosis at admission										
Medical	0.52	0.40–0.67	0.77	0.58–1.00	213	147	360	206	98	304
Respiratory failure	0.55	0.37–0.77	0.48	0.33–0.69	139	87	226	133	42	175
Sensory impairment/seizure	0.70	0.30–1.50	0.94	0.43–2.08	28	18	46	20	9	29
Metabolic/dehydration	1.25	0.28–4.67	0.71	0.14–4.03	7	11	18	8	5	13
Cardiovascular, congenital	1.00[b]	0.37–2.72	-[d]	-	1	1	2	9	6	15
Heart failure	0.57	0.21–2.21	1.13	0.52–3.42	7	6	13	6	17	23
Sepsis	1.00[b]	0.26–3.31	1.00[b]	0.24–4.91	2	6	8	7	4	11
Others	0.89	0.48–1.67	0.83	0.41–1.63	21	15	36	15	13	28
Surgical	0.86	0.63–1.24	0.87	0.62–1.23	56	83	139	68	62	130
Traumas	1.00[b]	0.11 – [c]	0.79	0.26–2.08	12	15	27	2	6	8
Patient complexity										
Baseline comorbid conditions	0.73	0.56–0.96	1.03	0.79–1.39	87	93	180	128	90	218
No comorbid conditions	0.62	0.43–0.84	0.69	0.50–0.95	195	151	346	148	76	224
Diagnosis at discharge[a]										
Respiratory, upper tract	1.23	0.46–3.03	1.20	0.35–6.66	7	5	12	11	6	17
Respiratory, lower tract	0.54	0.30–0.94	0.78	0.43–1.53	83	29	112	82	14	96
Respiratory, other	0.94	0.55–1.64	0.64	0.35–1.02	47	55	102	32	20	52
Cardiovascular, congenital	0.90	0.54–1.68	1.09	0.61–1.93	18	17	35	27	22	49
Cardiovascular, acquired	0.83	0.31–2.53	1.23	0.42–5.67	9	3	12	6	16	22
Neurologic	0.79	0.47–1.33	0.89	0.52–1.46	37	33	70	33	23	56
Gastrointestinal	1.14	0.53–2.88	0.97	0.48–2.13	10	13	23	7	16	23
Others	0.82	0.52–1.27	0.53	0.35–0.86	73	83	156	52	29	81

Incidence rate ratios are *IRR-1*, pre-COVID-19 incidence rate vs post-COVID-19 incidence rate in 2020; *IRR-2*, post-COVID-19 incidence rate in 2019 vs the incidence rate of the same period in 2020. [a] 37 patients were still in the PICU at the moment of data analysis; thus, no diagnosis at discharge was entered. [b] IRR computed using zero-inflated Poisson regression modeling due to different data distribution. [c] Infinite upper bounds. [d] IRR and CI were not reliable due to the small numerosity of the subgroup. Missing data: *n* (2019, 2020): age: 44 (21, 23); type of admission extra/-hospital/intra-hospital/surgery: 41 (24, 17); planned/not planned: 74 (34, 40); diagnosis at admission: 32 (31, 1); comorbid conditions: 33 (32, 1); diagnosis at discharge 4 (4, 0). *IRR*, incidence rate ratio

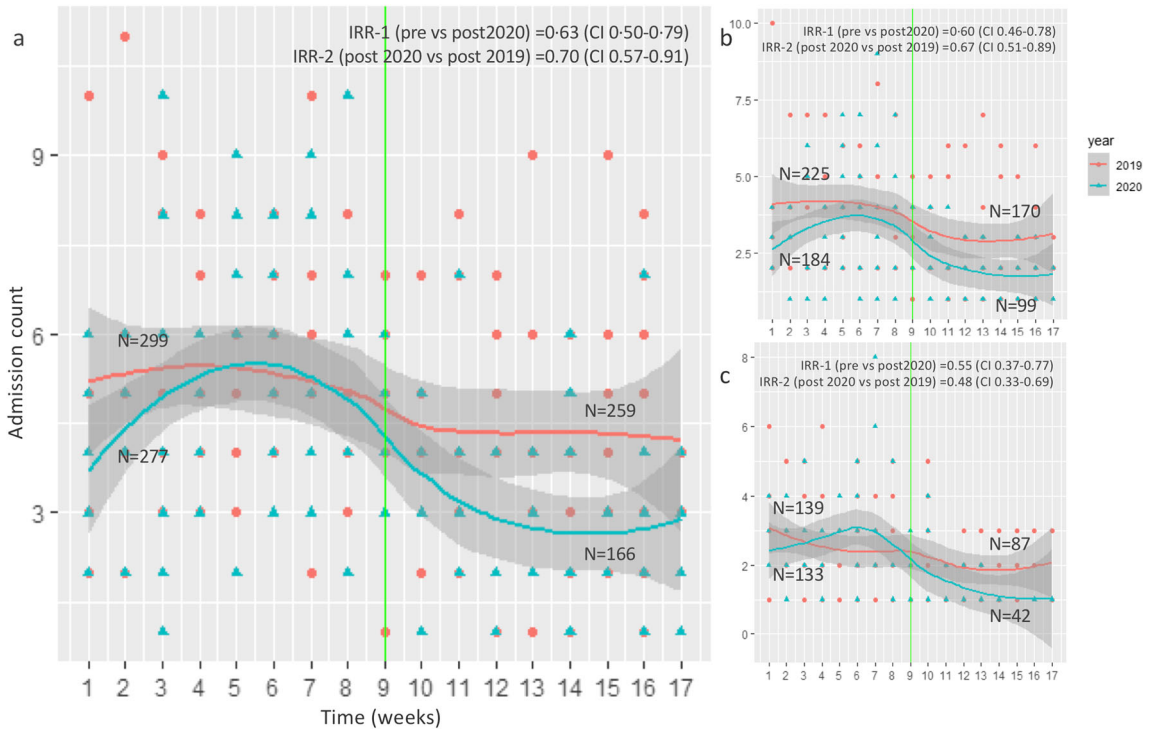

Fig. 1 a Overall trend of admissions to pediatric intensive care units in 2020 and 2019; b Trend of unplanned admissions; **c** Trend of admissions of patients with respiratory failure. Data refer to the period included from 8-weeks-before to 8-weeks-after the first administrative lockdown decree (24th February, green line). Lines represent the incidence rate and 95% confidence interval (dark gray area) modeling over time. Incidence rates and incidence rate ratios evaluating incidence rate differences between pre- and post-COVID-19 periods in 2020 (IRR-1), as well as between the post-COVID-19-period with the same period in 2019 (IRR-2), were computed using zero-inflated negative binomial or Poisson regression modeling, and bootstrapping process for CIs. *N* is the total count per subgroup

has been one of the main goals of the pediatric modern medicine. Here, we are looking at an event that has spontaneously reduced the PICU admissions by 30–50%. Although we do not have a clear scientific explanation of this phenomenon, we believe this represents an important message to the scientific community and Health Systems. We may speculate that the implementation of lockdown measures [6], social distancing, mask-wearing, travel restriction, and the consolidation of the hygiene practices might have reduced the transmission of other respiratory pathogens. Certainly, the human being cannot live under restrictive measures forever, but if restrictive measures were able to significantly reduce the rate of PICU admissions, it is worthy to analyze which measures can be reproduced within a healthy and constructive approach, e.g., reorganization of day cares or increasing the awareness on the importance to isolate symptomatic subjects.

An additional finding of our analysis was that the trend of admissions of comorbid patients significantly decreased during the outbreak, although it is not significantly different from 2019. Since comorbid patients are at higher risk of both PICU admission and COVID-19 disease, we could hypothesize that an effective strategy of domiciliary care might have been implemented during the outbreak for these patients. It is also possible that comorbid patients refrained from seeking specialized care during the outbreak. However, a spontaneous resolution of a moderate disease in comorbid patients would be extremely rare, and the overall mortality rate did not significantly differ from 2019.

Some limitations should be taken into consideration when interpreting these results. Although data were prospectively collected and all admitted patients were included in the registry, this remains a retrospective analysis and a small amount of data was missing. Additionally, no data regarding specific respiratory pathogens (other than COVID-19) were included. Finally, it was not possible to stratify the severity of comorbid conditions.

In conclusion, our study showed that unplanned and medical PICU admissions, especially those for respiratory failure, significantly decreased during COVID-19-outbreak. Further studies are needed to address the complex reasons underlying these significant changes, but we believe this report can guide and help physicians and health systems in being aware of the complex adjustments of events around a pandemic and identifying new strategies of prevention.

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Authors' Contributions Dr. Sperotto, Dr. Amigoni, Dr. Gregori, Dr. Ocagli, and Dr. Comoretto had full access to all data and take responsibility for the integrity of the data and the accuracy of the data analysis. Dr. Sperotto, Dr. Wolfler, Dr. Gregori, and Dr. Amigoni had a major role in the study design, interpretation of data, and drafting of the manuscript. Dr. Gregori, Dr. Ocagli, Dr. Comoretto, and Dr. Sperotto performed the statistical analysis. All authors performed a critical revision of the manuscript for important intellectual content and approved the final version.

Compliance with ethical standards

Conflict of interests The authors declare that they have no competing interests.

Ethical statement Ethics Committees of each Center approved the use of the Registry within the Network for no-profit research purposes, with a waiver for informed consent due to the observational nature of the project and anonymity of data.

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