

# Logistical and Medical Aspects of SARS-CoV-2 Pandemic Influencing Swiss Pediatric Intensive Care Units

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## Research Article

**Keywords:** pediatric intensive care unit burden, SARS-CoV-2 pandemic in children, pediatric multisystem inflammatory syndrome temporally associated with SARS-CoV-2, PIMS-TS, multisystem inflammatory syndrome in children, MIS-C

**Posted Date:** May 14th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-488558/v1>

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# Abstract

The impact of the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) pandemic on pediatric intensive care units (PICUs) is difficult to quantify. We conducted a retrospective cohort study in all eight Swiss PICUs between 02-24-2020 and 06-15-2020 to characterize the logistical and medical aspects of the pandemic and their impact on Swiss PICUs.

Out of the 1113 patients under the age of 20, who were tested positive for SARS-CoV-2 in Switzerland during the study period, 6% (63/1113) had to be hospitalized. All nine patients requiring intensive care had pediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2 (PIMS-TS) and constituted 14% (9/63) of all hospitalized patients. The patients presented with multiple organ dysfunction, needed longer stays in PICUs ( $p < 0.0001$ ) and longer positive pressure ventilation ( $p = 0.025$ ) than the regular PICU patients. They caused a higher workload (total Nine Equivalents of nursing Manpower use Score (NEMS) points,  $p = 0.0008$ ) and were classified to higher workload categories ( $p < 0.0001$ ) than regular PICU patients ( $n = 4881$ ) in 2019. PICU burden was also influenced by different logistical factors such as cancellation of planned surgeries and staff recruitment to adult wards.

*Conclusions* The different logistical and medical factors associated with the pandemic influenced the workload of the individual PICUs differently, depending on the presence of the single factors and their temporal relationship. The experiences of the study period help further to organize Swiss PICUs during the current pandemic to reduce the workload and optimize occupancy.

## Introduction

Pediatric intensive care units (PICUs) and children's hospitals in Switzerland were hardly influenced at the inception of the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) pandemic. In comparison to adults, children have been reported to infrequently be affected by SARS-CoV-2, constituting only 2 to 8% of all reported cases [1–3]. In addition, they seem to experience milder disease courses, as only 0.2-2% of all affected children have been severely or critically ill [1, 4, 5]. However, a few months into the pandemic, Swiss children's hospitals got affected by different logistical and medical aspects of the pandemic. In the course of the pandemic clusters of severely affected pediatric patients with symptoms similar, although distinctively different from severe Kawasaki disease were reported in Europe and North America [6–9]. This new syndrome was named pediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2 (PIMS-TS) or multisystem inflammatory syndrome in children (MIS-C) [3, 8]. Its clinical and laboratory presentations have been described in depth in a series of case reports and case series by now [6–12]. Most of the patients diagnosed with PIMS-TS have been treated according to protocols used for Kawasaki disease but a high need for organ supportive measures has been reported [3, 7, 13]. Besides having to care for patients with this new syndrome, PICUs were confronted with organizational issues arising from temporary regulations put in place by the federal council due to the pandemic.

There are eight PICUs in Switzerland, distributed all over the small country of 41 285 square kilometers with 8.6 million inhabitants [14, 15]. Two PICUs are located in the French speaking part, six PICUs in the German speaking part and none in the Italian speaking part of Switzerland.

The aim of our study is to analyze the different logistical and medical challenges facing the Swiss PICUs during the first wave of the SARS-CoV-2 pandemic.

## Materials And Methods

### PICU burden

All eight Swiss PICUs provided data on organizational characteristics and the situation in their units during the study period. These included general characteristics (total number of beds, total number of admissions, affiliation to adult hospitals) and characteristics related to the SARS-CoV-2 pandemic (percentage of scheduled admissions, cancellation of interventions, staff recruited to adult wards, percentage of PIMS-TS patients of all admissions).

For comparing workloads, the Nine Equivalents of nursing Manpower use Score (NEMS) and Riker Sedation-Agitation Scale (SAS) as well as a Swiss derivative of the two, the Swiss Society of Intensive Care Medicine (SSICM) shift categories were used [16–18]. NEMS includes data on interventions as well as of therapies and reflects the workload of nurses and physicians. The score includes the following nine items: basic monitoring, intravenous medication, mechanical ventilator support, supplementary ventilator care, single vasoactive medication, multiple vasoactive medication, dialysis techniques, specific interventions in the intensive care unit (ICU) and specific interventions outside the ICU [16]. The higher the NEMS Score, the more nursing manpower was needed during a certain shift or during the whole ICU stay. SAS is used to evaluate a patients’ level of sedation and agitation. During each shift each patient is given a score from one to seven ranging from an unarousable patient to a dangerously agitated patient [17]. SSICM shift categories integrate NEMS and SAS, category 1A of the SSICM defines the most, and category 3 the least, work-load intensive shift for ICU nurses [18]. Details SSICM shift categories are shown in Table 1.

Table 1  
Classification criteria for the Swiss Society of Intensive Care Medicine (SSICM) shift categories.

Category	1A	1B	2	3
Criteria	NEMS > 30 or NEMS ≥ 21 and SAS > 5	NEMS 21–30 and SAS ≤ 5 or NEMS 13–20 and SAS > 5	NEMS 13–20 and SAS ≤ 5 or NEMS < 13 and SAS > 5	NEMS < 13 and SAS ≤ 5
NEMS – Nine Equivalents of nursing Manpower use Score, SAS – Riker Sedation-Agitation Scale				

Table 2

General characteristics and characteristics related to the pandemic of the 8 Swiss pediatric intensive care units between 02-24-2020 and 06-15-2020

Characteristics	PICU 1	PICU 2	PICU 3	PICU 4	PICU 5	PICU 6	PICU 7	PICU 8
<b>General characteristics</b>								
Children's hospital not affiliated to adult hospital	yes	no	no	no	no	no	yes	yes
Number of PICU beds	8	12	9	7	12	11	10	25
ECMO center	no	yes	no	yes	yes	no	no	yes
Perform hemodiafiltration	no	yes	no	yes	yes	yes	no	yes
<b>Characteristics related to the pandemic</b>								
Total number of admissions	115	224	99	265	168	156	136	365
Total NEMS points per patient	237	219	262	186	466	164	305	294
Percentage of scheduled admissions	24%	49%	9%	16%	51%	24%	27%	49%
Cancellation of scheduled interventions	yes							
Staff recruited to adult wards	yes	no	yes	yes	yes	yes	no	no
Percentage PIMS-TS patients of all admissions	0.9%	0	0	1.5%	1.8%	0	0	0.3%
Number of positive SARS-CoV-2 PCR patients without PIMS-TS	0	0	0	0	0	0	0	0
ECMO – extra corporal membrane oxygenation, NEMS – Nine Equivalentents of nursing Manpower use Score, PCR – polymerase chain reaction, PICU – pediatric intensive care unit, PIMS-TS – pediatric inflammatory multisystem syndrome temporally associated with severe acute respiratory syndrome coronavirus-2, SARS-CoV-2 - severe acute respiratory syndrome coronavirus-2								

Table 3

Comparison of PIMS-TS patients and all PICU patients hospitalized in 2019 based on quantitative and qualitative measures of case complexity.

Characteristics	PIMS-TS patients	All patients in 2019	p value
	n (patients) = 9 n (shifts) = 273	n (patients) = 4881 n (shifts) = 63015	
Quantitative measures, median (IQR)			
Length of stay in days	10 (9–11)	1.6 (0.8–3.9)	< 0.0001
Duration of positive pressure ventilation in hours	72 (0–99)	0 (0–24)	0.025
PIM2 on admission	4.3 (1.5–7.2)	1.4 (0.6–3.2)	0.07
Total NEMS points	569 (496–736)	92 (51–239)	0.0008
Qualitative measures, number of shifts (percentage)			
SSICM shift categories			
1A+1B	156 (57.1)	23557 (37.4)	0.0001
2+3	117 (42.9)	39458 (62.6)	
Riker SAS			
SAS ≥ 5	33 (12.1)	6523 (10.4)	0.35
SAS < 5	240 (87.9)	56492 (89.6)	
IQR – interquartile range, NEMS – Nine Equivalents of nursing Manpower use Score, PICU – pediatric intensive care unit, PIM2 – Pediatric Index of Mortality 2, PIMS-TS – pediatric inflammatory multisystem syndrome temporally associated with severe acute respiratory syndrome coronavirus-2, SAS – Sedation-Agitation Scale, SSICM – Swiss Society of Intensive Care Medicine			

## Patient and population data

Data was retrospectively gathered in all eight Swiss PICUs on patients hospitalized from February 24, 2020, the date on which the first SARS-CoV-2 PCR positive patient was reported in Switzerland, up until the June 15, 2020.

Inclusion criteria were age below 20 years and a positive SARS-CoV-2 polymerase chain reaction (PCR) result or the diagnosis of PIMS-TS according to either the Royal College of Child Health and Pediatrics [19], the World Health Organization [20] or the Centers for Disease Control and Prevention case definitions [21], during the PICU stay. Patient data was collected from chart notes and anonymized in the respective centers with a custom made questionnaire, one center's data was obtained from the *Risk Stratification in COVID-19 patients in the ICU (RISC-19-ICU)* registry [22]. Information was gathered also on the use of anti-

inflammatory medications including corticosteroids, intravenous immunoglobulin, anakinra and tocilizumab, which all have been licensed for use in other conditions but were used off label for PIMS-TS.

In order to compare the critically ill SARS-CoV-2 pediatric patients to the regular PICU population, data on all patients hospitalized in the eight Swiss PICUs in 2019 was used. The whole year instead of the corresponding time period in 2019 was used to avoid a seasonal bias in the group representing regular PICU patients. This data was drawn from the Minimal Dataset of the Swiss Society of Intensive Care Medicine (MDSi) [23]. The Pediatric Index of Mortality 2 (PIM2) was used as an indicator of predicted case severity of the patients with PIMS-TS and the general PICU population [24]. General epidemiological data on the SARS-CoV-2 pandemic in Switzerland was drawn from the official website of the Swiss Federal Office of Public Health (FOPH) [25]. As no reliable serological data was available at the whole population level, the total number of SARS-CoV-2 PCR positive tests in Switzerland was used in calculations to represent number the SARS-CoV-2 cases despite our PIMS-TS group mostly being PCR negative and seropositive. Data on the demographics of Switzerland was obtained from the website of the Swiss Federal Statistical Office [14].

## Definitions of organ dysfunction

Acute respiratory distress syndrome (ARDS) was defined according to the Pediatric Acute Lung Injury Consensus Conference definition for pediatric acute respiratory distress syndrome [26]. Shock was defined as an arterial systolic blood pressure below the, age adapted, 5th percentile or a systolic blood pressure below two standard deviations of the age adapted mean, and/or the need for vasoactive support to maintain blood pressure in the range [27, 28]. Myocardial injury was defined as an elevation of creatine kinase myocardial band (CK-MB) or troponin T above the age adapted reference limit, and/ or a quantitatively reduced ejection fraction assessed by transthoracic echocardiography. Renal dysfunction was defined according to the pRIFLE classification [29]. Hepatic dysfunction was defined as the elevation of liver enzymes above the age adapted reference and elevation of prothrombin time [30]. A reduction of the prothrombin time below, or a prolongation of activated partial thromboplastin time above, the age adapted reference limit were classified as coagulation disorders.

## Results

### PICU burden

The Swiss PICUs varied in general characteristics as well as in characteristics related to the pandemic. The different medical and logistical aspects affecting the PICUs are listed in Table 2. During the pandemic all Swiss PICUs were affected by logistical and organizational issues independent of admitting children with PIMS-TS. Four out of eight PICUs had patients admitted with PIMS-TS between February 24, 2020 and June 15, 2020. Patients with PIMS-TS constituted 0.6% of all Swiss PICU admissions (9/1528) during this time period. A comparison of patients with PIMS-TS and general pediatric intensive care unit patients hospitalized in 2019 is shown in Table 3, based on quantitative and qualitative measures of case complexity. Patients with PIMS-TS had higher total NEMS scores ( $p = 0.0008$ ) and were classified to

higher SSICM workload categories more frequently than general PICU patients hospitalized in 2019 ( $p < 0.0001$ ).

### Epidemiology of SARS CoV-2 positive patients

The total of 1113 children and young adults under the age of 20 were tested positive for SARS-CoV-2 infection between February 24, 2020 and June 15, 2020 in Switzerland, of which 6% (63/1113) had to be hospitalized (Swiss FOPH [25]). Ten pediatric patients with a concurrent positive SARS-CoV-2 PCR result or with PIMS-TS were hospitalized in PICUs. The only patient not diagnosed with PIMS-TS was admitted to the PICU due to an acute necrotizing encephalopathy. As the role of SARS-CoV-2 in the pathogenesis and disease progression remained unclear in this case, this patient's data was excluded from the present analysis. The nine remaining patients with PIMS-TS hospitalized in Swiss PICUs constituted 14% (9/63) of all SARS-CoV-2 positive hospitalized and 1% (9/1113) of all SARS-CoV-2 positive children and young adults under the age of 20 in Switzerland during that period (Swiss FOPH (19)). The incidence of severe PIMS-TS requiring hospitalization at a PICU was therefore 0.5 per 100 000 people under the age of 20 during the study period.

The first patient with PIMS-TS presented in late April, during calendar week 15. The temporal distribution of the PIMS-TS cases and their relationship to the progression of the pandemic in Switzerland is illustrated in Figure 1. The general characteristics of all the PIMS-TS patients, details on organ dysfunction and applied therapies are presented in supplemental material.

## **Discussion**

In this study we highlight the different aspects of the first wave of the SARS-CoV-2 pandemic influencing PICUs in Switzerland. Although initially the disease was thought to affect predominantly adult departments, in the course of the pandemic, pediatric units and PICUs were more and more affected. Our results show that the absolute number of pediatric patients requiring intensive care due to severe SARS-CoV-2 and PIMS-TS during the study period was low. However, PIMS-TS patients requiring intensive care constituted a relatively large proportion (14%) of all hospitalized patients with laboratory confirmed SARS-CoV-2 under the age of 20 years. Similar results of hospitalized children and adolescents admitted to PICUs have been reported in other studies [31, 32].

In our study the PIMS-TS patients presented about 4 to 5 weeks after the peak of the total number of new SARS-CoV-2 cases in the general population (Figure 1) supporting the notion of PIMS-TS being a post-infectious phenomenon. Similar temporal distributions have been shown in other studies [33].

The profile of organ supportive therapies used in our study population was alike to that described in other studies [13, 34]. Regarding the employment of anti-inflammatory medication, Davies *et al.* described approximately 70% PICU patients with PIMS-TS receiving steroids and 70% receiving intravenous immunoglobulin, which correlates with the here presented data [34]. However, and opposed to the 67% in our cohort, use of biological agents in that study was limited to 20% [34]. This is likely to be explained by

the novelty of the disease, the low caseload per each individual Swiss PICU, and the lack of evidence and consensus on optimal treatment protocols. Evidence in the form of randomized controlled trials remains scarce. Although Switzerland is a small country, eight independent PICUs treat critically ill children. Each PICU is quite small, operating a relatively small number of beds. Although cooperation between the PICUs exists in several forms, every day professional exchange is not intensive. However, in the course of the first wave of the pandemic, the PICUs recognized, that it is important to cooperate, to coordinate actions and to exchange experiences with each other to improve the management of these patients. As a consequence, Swiss consensus guidelines for best practice were established by a multidisciplinary group of Swiss pediatric clinicians with expertise in intensive care, immunology, rheumatology, infectious diseases and hematology during the second wave of the pandemic at the end of 2020 (<http://transfer.imk.ch/f.php?h=3R2LIffV&d=1>).

Although few in numbers and with a low predicted mortality, PIMS-TS patients required a high resource load per case to manage. Our data shows, that PIMS-TS patients remained longer in PICUs and required positive pressure ventilation for a longer time period than general PICU patients. In addition, their management caused a higher workload as illustrated by the bigger proportion of shifts with a higher SSICM categories as well as higher total NEMS scores. This mirrors the complexity of these cases and the strain they bring to PICUs.

At the beginning of the pandemic a variety of measures to prepare the Swiss hospital network for the pandemic were instituted on federal as well as regional levels. Due to the decentralized governmental system of Switzerland those measures varied markedly between different regions. Similar measures were applied to children's and adult hospitals in the same region. Scheduled interventions were cancelled to reduce the need for postinterventional intensive care and to increase resources for emergency admissions. In some hospitals skilled PICU staff was recruited to support the adult ICUs forcing PICUs to temporally operate with a reduced number of team members. Those different logistical factors, in addition to the burden of PIMS-TS patients, influenced the workload and the occupancy of the individual PICUs differently, depending on the presence or absence of the single factors and their temporal relationships. Due to their complexity the exact quantification and comparison of the impact of all of these factors was unfortunately not possible. Thanks to the experiences of the first wave, we recognize that the individual PICUs should be organized by a regional and not, federal level and in accordance with but not the same to the surrounding adult hospitals. A contemporary analysis of the burden and duties of the individual PICU is essential to reduce the workload of the PICU and simultaneously to ensure the bed occupancy for economic reasons.

Our work is unique for several reasons. It is a comprehensive analysis of all of the relevant cases in our entire country, a feature other works published to date have not been able to offer. The exhaustive coverage enables us also to put our patient numbers into a bigger context through comparisons with epidemiological data on less severely affected patients as well as our whole population. In addition, we put emphasis on evaluating case severity and workload and conducted a comparative analysis with data on general PICU patients hospitalized in the previous year. Furthermore, we analyzed organizational

factors influencing PICUs not strictly related to the affected patients but rather the general situation in the Swiss healthcare system which also took a toll on the PICUs during first wave of the pandemic, an aspect that has received little coverage until now.

Our study has some limitations. The retrospective design restricts the range of data available from the study population, this applies for both the historical comparison cohort as well as the epidemiological PIMS-TS data. Further, the low case number of PIMS-TS patients limits the generalizability of these results to other countries and health-care settings. However, the aim of this study was to analyze the data of Switzerland, the data of a small country with several PICUs, organized in a decentralized manner. In addition, the vast array of logistical factors influencing the PICUs during the pandemic was not quantifiable.

In conclusion, the SARS CoV-2 pandemic does not exclusively affect adult ICUs, with PICUs also having to face a variety of eventualities with a plethora of consequences. PIMS-TS patients are, although few in numbers, demanding to manage, especially in light of the multitude of logistical changes burdening PICU teams during the pandemic. As pandemic continues, reflecting and learning from experience is essential to reduce the workload and optimize the occupancy in each individual PICU.

## **Declarations**

### Ethical approval

The study proposal (KEK: 2020-00720), as well as the RISC-19-ICU (KEK: 2020-00322, ClinicalTrials.gov Identifier: NCT04357275) registry have been evaluated by the Cantonal Ethics Committee of Zurich, a member of the Swiss Association of Research Ethics Committees – Swissethics and in line with the Swiss Federal Human Research Act deemed exempt from the need for additional ethics approval. The study complies with the Declaration of Helsinki, the Guidelines on Good Clinical Practice (GCP-Directive) issued by the European Medicines Agency as well as the Swiss law and Swiss regulatory authority requirements and has been designed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies.

### Statistical analysis

Statistical analysis was conducted employing the R environment for statistical computing version 4.0.2. Comparisons of population characteristics were performed using Wilcoxon rank-sum test for continuous not normally distributed and the chi-squared test for categorical variables. Continuous not normally distributed data is presented as median with interquartile ranges (IQR) and nominal data as counts and percentages.

### Acknowledgements

Tilman Humpl (University Hospital of Bern, Department of Pediatric Intensive Care), Thomas Riedel (Cantonal Hospital Graubunden, Department of Pediatrics), Peter Rimensberger (University Hospital of

Geneva, Division of Neonatology and Pediatric Intensive Care, Department of Pediatrics), Bjarte Rogdo (Children's Hospital of Eastern Switzerland, Neonatal and Pediatric Intensive Care Unit), Martin Stocker (Children's Hospital Lucerne, Neonatal and Pediatric Intensive Care Unit) and the *RISC-19-ICU* collaborators represented by Thierry Fumeaux (Hospital of Nyon, Switzerland, Intensive Care Unit), Philippe Guerci (University Hospital of Nancy, France, Department of Anesthesiology and Critical care Medicine), Jonathan Montomoli (Erasmus medical Center, Rotterdam, Netherlands, Department of Intensive Care Medicine), Reto Schüpbach (University Hospital of Zurich, Zurich, Switzerland, Institute of Intensive Care Medicine).

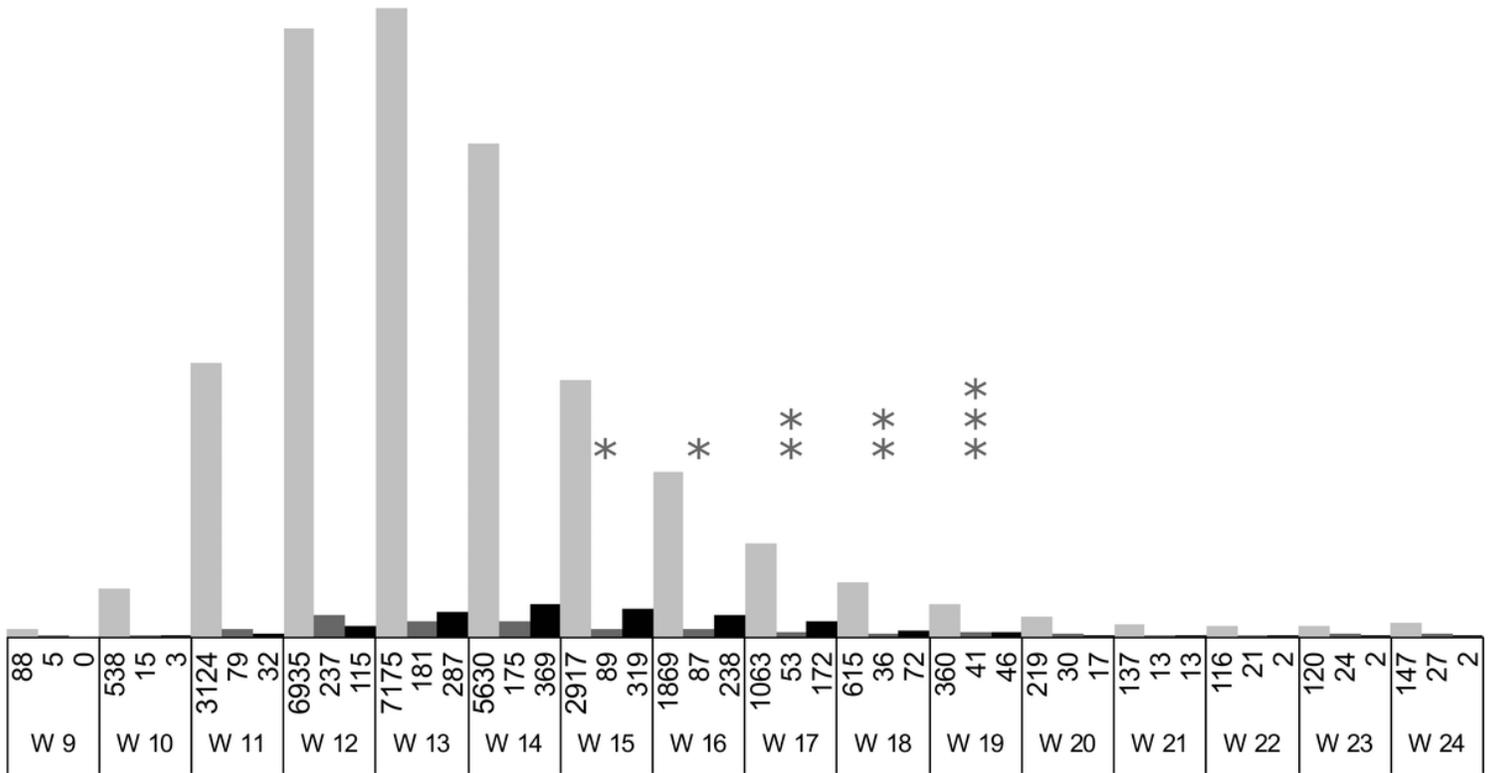
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## Figures



**Figure 1**

Progression of the first wave of the SARS-CoV-2 pandemic in Switzerland and the time of presentation of PIMS-TS cases. The total number of new laboratory confirmed SARS-CoV-2 cases per week is depicted in light grey, the number of new laboratory confirmed cases per week in children and adolescents (ages 0-19) in dark grey, the number of overall deaths with a laboratory confirmed SARS-CoV-2 in black (data drawn from Swiss FOPH [25]). Each asterisk represents a patient presenting with PIMS-TS.

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