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The COVID-19 Pandemic and the Hospital Surge Preparedness and Response Index: A Retrospective Study in an Italian Hospital

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Original Research

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Abstract

Objective: To quantitatively assess key performance indicator changes between selected pre-pandemic and pandemic periods at the Sant'Anna Hospital emergency department (ED) in Como, Italy through the retrospective use of Hospital Surge Preparedness and Response index (HSPRI).

Methods: This study collected the average length of stay (LOS), time-to-physician initial assessment (TPIA), and left-without-being seen (LWBS) rates for 2 pre-pandemic (control group) and 3 pandemic periods (study group) in the COVID ED (C-ED) dedicated to treat COVID-19 patients and the non-COVID ED (NC-ED) dedicated to non-COVID cases. Quantitative analysis was based on hypothesis testing. A retrospective qualitative theme and subtheme analysis based on the HSPRI was conducted on baseline strategies before each pandemic period and on the actions implemented thereafter.

Results: LOS increased across all pandemic periods. TPIA decreased in the first 2 pandemic periods in comparison to pre-pandemic. LWBS decreased between pre-pandemic and pandemic periods. Of the 22 action items listed in the HSPRI, 8 were implemented in the first pandemic period, 8 in the second and 1 in the third, for a total of 17 items.

Conclusions: The HSPRI demonstrated value as a tool for a hospital staff to actively utilize during a pandemic to identify KPI triggers to formulate actions to maintain pre-pandemic care or ameliorate the deterioration of care during the pandemic.

The Italian health system lacked appropriate preparedness to respond to the surge in patients in March 2020 at the beginning of the Coronavirus disease 2019 (COVID-19) pandemic and emergency departments (EDs) faced challenges accessing resources.[1] The Sant'Anna hospital in Como, Italy, did not have a focused and operational emerging infectious disease surge response plan but did have an all-hazard emergency plan that was not updated nor fully utilized since its inception in 2014, requiring hasty implementation of outdated and immature plans to increase surge capacity.[2,3]

There have been theoretical examples of ED surge response strategies,[4–5] like the Hospital Surge Preparedness and Response Index (HSPRI),[6,7] the result of a 2021 Delphi study that links triggers to surge response action items across the surge capacity all-hazard response continuum. This tool should be adopted and adapted for specific EDs to provide a framework to maintain care, or ameliorate the deterioration of care, compared to pre-incident performance levels based on their facility's current service capacity and capabilities. However, consensus on surge response strategies during the COVID-19 pandemic was fragmented as such reports were based on pre-pandemic concepts or have not been validated.

Key Performance Indicators (KPIs) for assessing the performance of a single ED or to compare the performance of any number of EDs have been published.[8–9] Some have tried to evaluate changes in a single or a series ED KPIs to link these changes to different surge capacity models during non-pandemic disasters, [10–11] but there is scarcity of literature on how ED KPIs change in relation to adopted and adapted surge response actions triggered by pandemics like COVID-19.[12]

The objective of this study was to quantitatively assess ED KPIs across selected pre-pandemic and pandemic periods at the ED of the Sant'Anna Hospital of San Fermo della Battaglia, Como, Italy, which serves a population of nearly 600,000 people, and to relate these to adopted and adapted surge response actions for crisis capacity identified by the HSPRI. The aim is to examine the

relationship between these performance fluctuations and the surge response actions adopted and adapted by the staff at Sant'Anna.

Methods

The study focused on the ED and its subdivision during the COVID-19 pandemic: COVID ED (C-ED) dedicated to infected patients or to patients with suspected infection, and Non-COVID ED (NC-ED), dedicated to all other casualties.

This study considered a total of 5 periods of 3 months each:

- Pre-pandemic
  - A: March – April – May 2019
  - B: October – November – December 2019
- Pandemic
  - X: March – April – May 2020
  - Y: October – November – December 2020
  - Z: March – April – May 202

Periods A and B were used for controlled comparison and for baseline calculation. Periods X, Y, and Z represented the study groups and the first 3 periods of the COVID-19 pandemic in Northern Italy. The study periods X, Y, Z have been selected as periods of 3 months where an anomalous increase, a peak, and a decrease in COVID-19 patients was recorded in the area that the hospital services (see Figure 1A of the Online Data Supplement).

Data collection and processing was based on a mixed methodology. Quantitative data collection and hypothesis testing was followed by a qualitative theme and subtheme data assessment, as described below.

Quantitative Data Collection

From periods X, Y, and Z only the days of "hyper-in-flow" (HI) have been considered, defined at Sant'Anna hospital as an ED patients' in-flow greater than 142 patients for the NC-ED or greater than 10 patients for the C-ED in 1 day.[2] The concept of HI has been internally created and introduced to Sant'Anna at the beginning of the pandemic, and periods A and B are exempted from this calculation and have been considered in toto.

The following KPIs were obtained specific to Sant'Anna:

- Length of stay (LOS): mean time interval (in minutes) between patient being triaged and discharged from both the NC-ED and C-ED.
- Time-to-physician initial assessment (TPIA): mean time (in minutes) from patient triage to first assessment by a physician in both NC-ED and C-ED.
- Left-without-being seen rates (LWBS): percentage of patients who left the ED without an assessment by a physician or their delegate. Given legal mobility restrictions of SARS-CoV-2 affected patients, only data from the NC-ED was included.

Data was collected from patient in-flow to the general ED excluding the separate fast track for pediatric, OB/GYN, ophthalmologic, oncologic, and orthopedic patients. In Italy, patients present to triage and are sorted depending on their chief complaint, with specific protocols to send specific patients to the specialty treatment area (consultants) specific to their chief complaint. For each patient during HI days, data conducive to KPIs calculation were collected, as summarized in Table 1A of the Online Data Supplement.

Quantitative data analysis was based on hypothesis testing to assess performance through KPIs pre- and post-intervention. The study considered a 95% confidence interval. Microsoft® Excel (2021) was used for statistical analysis. The analyses:

1. Null-hypothesis testing:
   a. H_0: KPIs for non-COVID (control) and COVID (study) periods are not statistically different.
   b. H_A: KPIs for control and study periods are statistically different.
   KPIs have been compared between control groups and study groups: A v X; A v Z; B v Y. This first step provided a background to assess correlation between the pandemic and the surge response actions and changes in KPIs.
2. Null-hypothesis testing:
   a. H_0: KPIs did not change between the COVID phases
   b. H_A: KPIs did change between the COVID phases
   KPIs between the study groups: X v Y; X v Z; Y v Z. This analysis provided information on KPIs changes, if any, across the pandemic periods, in relation to surge response actions.

Qualitative Theme and Subtheme Data Collection

In February 2020, a Crisis Unit (CU) and a COVID Coordination Team (CCT) were created. The CU defined general guidelines and hospital policy, issued strategical decisions, and functioned as a roundtable across cornerstone assets of the hospital. The CCT was the executive wing of the CU.

Qualitative data collection focused on baseline surge response strategies enacted before March 2020 and on adopted and adapted surge response actions implemented across period X, Y, and Z. This included a qualitative theme and subtheme data collection and analysis based on the action items for crisis capacity identified by the HSPRI.[6,7]

A qualitative description of the interventions implemented at Sant'Anna before, during and after each study pandemic period that corresponded to the action items highlighted by the HSPRI, if any, were collected. Content analysis of Sant'Anna protocols and organizational plans internally published was conducted. Three discussion rounds held between June and August 2021 among the authors FF – member of the CU and CCT – RS, and MC – members of the CU – led by PR provided additional information. Notes were taken during the discussions and content analysis of collected notes was conducted. The resulting document that matched the action items for crisis capacity identified by the HSPRI with the surge response actions adopted at Sant'Anna has been examined by authors FF, RS, and MC and misreported information was corrected. Ethical approval to conduct this study has been granted by Comitato Etico dell'Insubria, Varese, Italy.

Results

Quantitative Assessment of KPIs and Hypothesis Testing

A total of 11 317 patients visited the ED in period A and 10 791 in period B. A total of 2572 patients visited the ED during the 50 HI days of period X, versus the 3910 patients of the 57 HI days of period Y and the 4308 patients of the 56 HI days of period Z.

Average length of stay (LOS) increased during the pandemic in comparison with the control periods. Average LOS increased progressively along the pandemic periods (Table 1 and Figure 1). Differential assessment of LOS changes showed that LOS in the Non-COVID ED was lower than LOS in the COVID ED for all the periods, as portrayed in Table 1 and Figure 2A of the Online Data Supplement. An average

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Table 1. Comparison of average length of stay (LOS) between the control and study periods and average LOS in NC-ED and C-ED across the pandemic periods X, Y and Z

Period	Mean (min)	Size (n)	Period	Mean (min)	Size (n)	Difference with 95% CI (min)	*P* value
A	383	11317	X	407	2572	24 [10.65; 37.55]	0.0004
A	383	11317	Z	460	4308	77 [66.38;88.82]	0.0001
B	406	10791	Y	470	3910	64 [50.63;77.83]	0.0001
X	407	2572	Y	470	3910	63 [44.00; 82.44]	0.0001
X	407	2572	Z	460	4308	53 [35.03; 71.97]	0.0001
Y	470	3910	Z	460	4308	–10 [–26.23; 6.79]	0.2473

Period	X (min)	Y (min)	Z (min)
NC-ED	327	431	441
C-ED	541	580	578
ED	407	470	460

Above, this table depicts changes differences and their confidence intervals in average length of stay (LOS) across the controls (A and B) and the study (X, Y, and Z) periods. Below, it depicts the differential assessment of LOS changes in Non-COVID ED (NC-ED), COVID ED (C-ED), and total Emergency Department (ED) for the 3 pandemic periods X (March-May 2020), Y (October-December 2020), and Z (March-May 2021).

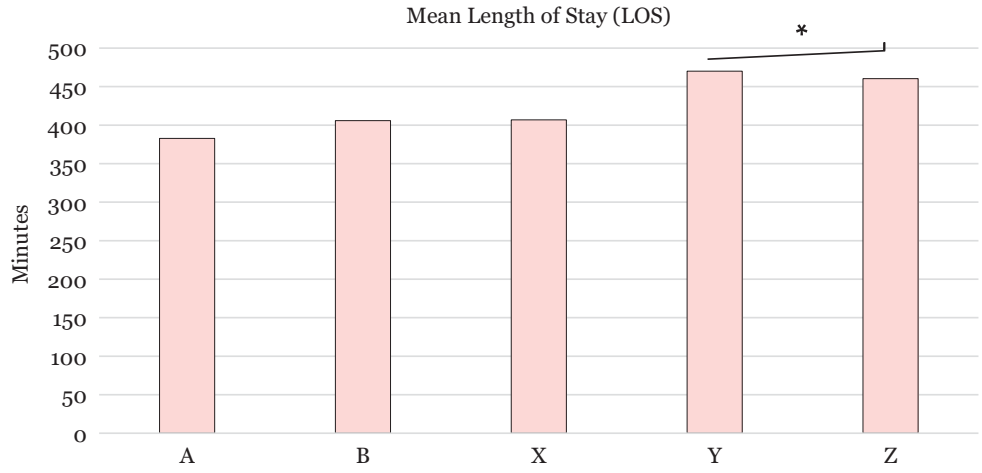

Figure 1. Mean overall length of stay (LOS) at the emergency department.
This graph shows the change in average LOS across the control and study periods. LOS is expressed in minutes. The symbol * indicates no significant difference between the marked periods. LOS: Length of stay A: March – May 2019. B: October – December 2019. X: March – May 2020. Y: October – December 2020. Z: March – May 2021.

time-to-physician initial assessment (TPIA) of 182 minutes and 201 minutes was recorded in period A and B. TPIA during period X was of 74 minutes, marking a 108-minute decrease from period A (P = 0.0001). Average TPIA during period Y was of 128 minutes, marking a decrease of 73 minutes from period B (P = 0.0001). No significant difference was found between A (182 minutes) and Z (178 minutes) (P = 0.2265).

Significant differences were recorded between the average TPIAs of the pandemic periods with a progressive increase from X to Z (Table 2 and Figure 2). Mean TPIAs for C-ED outperformed those of NC-ED in all the 3 periods as shown in Table 2 and Figure 3A of the Online Data Supplements. A decrease in left-without-being-seen (LWBS) rate was recorded between the control and the study periods (Figure 3 and Table 3).

Qualitative Assessment of Surge HSPRI Response

Staff

Workers were reallocated from the surgical disciplines in all 3 pandemic periods, whose activities were reduced during the surge peaks. Three doctors, 10 nurses, 1 career (a professional in charge of care of the patient's hygiene) and 1 porter (patient transporter) oversaw the C-ED. One porter was added to the team of the NC-ED during the day and 1 nurse for the night shift. The personnel plan was flexible and adaptable day by day. As reported by authors FF, RS, and MC, a spokesperson was defined for each ward at the beginning of period X to interface with the COVID Coordination Team (CCT) to coordinate personnel. Representatives of the CCT would do routine rounds in the wards to assess personnel situation.

Internal volunteers from different wards were recruited to create multidisciplinary teams for the wards that host COVID patients in period X. Starting from period Y, structured teams were introduced with at least 2 pulmonologists and 2 infective disease clinicians per team. External volunteers have been included throughout the pandemic to support in call centers and distribution of information to patients and other minor activities, as reported by authors FF, RS, and MC.

Spaces

The ED was separated into the C-ED and NC-ED at the beginning of period X, each with dedicated waiting rooms and triage areas.

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Table 2. Comparison of average time-to-physician initial assessment (TPIA) between the control and study periods and average TPIA in Non-Covid ED (NC-ED) and Covid ED (C-ED) across the pandemic periods X, Y, and Z

Period	Mean (min)	Size (n)	Period	Mean (min)	Size (n)	Difference with 95% CI (min)	*P* value
A	182	11317	X	74	2572	–108[–114.8;–100.5]	0.0001
A	182	11317	Z	178	4308	–4 [–10.29; 2.45]	0.2265
B	201	10791	Y	128	3910	–73 [–78.86; –66.92]	0.0001
X	74	2572	Y	128	3910	54 [46.88; 60.50]	0.0001
X	74	2572	Z	178	4308	104 [95.83; 111.63]	0.0001
Y	128	3910	Z	178	4308	50 [42.58; 57.50]	0.0001

Period	X (min)	Y (min)	Z (min)
NC-ED	87	139	189
C-ED	52	96	108
ED	74	128	178

Above, this table depicts changes differences and their confidence intervals in average TPIA across the controls (A and B) and the study (X, Y, and Z) periods. Below, it depicts the differential assessment of average TPIA in the COVID-FREE ED (NC-ED), COVID ED (C-ED), and total Emergency Department (ED) for the 3 pandemic periods X (March-May 2020), Y (October-December 2020), and Z (March-May 2021).

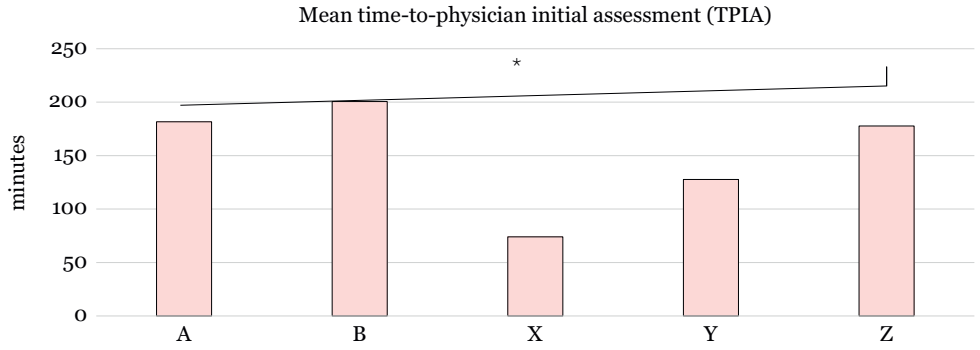

Figure 2. Mean overall time-to-physician initial assessment (TPIA) and the emergency department.
This graph shows the change in average TPIA across the control and study periods. TPIA is expressed in minutes. The symbol * indicates no significant difference between the marked periods. TPIA: time-to-physician initial assessment. A: March – May 2019. B: October – December 2019. X: March – May 2020. Y: October – December 2020. Z: March – May 2021.

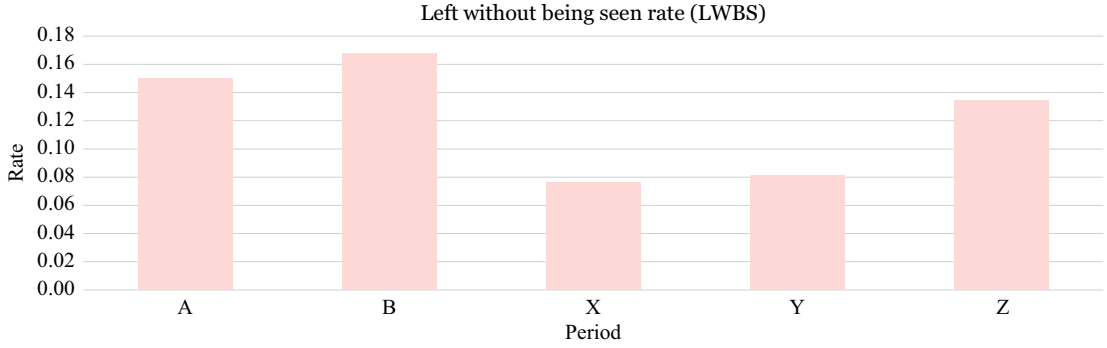

Figure 3. Overall left without being seen rate (LWBS) at the emergency department.
This figure depicts differences in LWBS rate between the control and the study periods. The symbol * indicates no significant difference between the marked periods. LWBS: Left without being seen rate. A: March – May 2019. B: October – December 2019. X: March – May 2020. Y: October – December 2020. Z: March – May 2021.

The dimensions of the departments were flexible according to rise and fall of patient in-flow. The plastic doors of the ambulance entry hallway were closed, and the area was converted into an acute observation area with 18 beds supplied with oxygen bottles. The hallway was used in April 2020 during period X because of the extreme pandemic peak and then routinely from period Y after it was structurally reconverted into a proper patient-hosting ED area with oxygen stations, adequate ventilation, video-monitoring, and safety plans. An adjacent area was included to the C-ED in period Y to increase capacity by 24 beds. Area division is shown in Figures 4A of the Online Data Supplement.

Following regional directives, the CU introduced transition beds. They hosted ED patients without COVID-related symptoms and with negative COVID-test for 24 hours before boarding. Contrary to regional directives, no fixed intra-hospital plan regarding the transition beds was enforced, given the day-by-day uncertainty

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Table 3. Comparison of left-without-being seen (LWBS) rate across the 5 studied periods (A, B, X, Y, and Z) with the respective *P* values

Period	Size (n)	LWBS (n)	LWBS rate (%)	Period	Size (n)	LWBS (n)	LWBS rate (%)	*P* value
A	11317	1698	15.0	X	1615	123	7.6	0.0001
A	11317	1698	15.0	Z	3690	497	13.5	0.0221
B	10791	1811	16.8	Y	2896	236	8.2	0.0001
X	1615	123	7.6	Y	2896	236	8.2	0.5287
X	1615	123	7.6	Z	3690	497	13.5	0.0001
Y	2896	236	8.2	Z	3690	497	13.5	0.0001

This table depicts the total number of patients of the periods considered, the number of patients that left the ED without being seen, and the LWBS rate. Furthermore, it shows the comparison between the LWBS rates of the considered periods, as mentioned in the methods section. As already stated, from period X, Y, and Z, only the Non-COVID ED (NC-ED) has been included in the comparison. ED: Emergency Department. LWBS: Left-without being seen. NC-ED: Non-COVID ED. Pandemic periods: X (March-May 2020), Y (October-December 2020), and Z (March-May 2021).

regarding the patient surge. A pre-triage tent for binary sorting was placed outside of the ED. Patients showing a body temperature higher than 37.5°C or symptoms attributable to COVID-19 infection were directed to the C-ED.

A so-called "fast-track" was introduced in period X. From triage, patients could bypass ED generalist's first assessment and be directed to consultants specific to their chief complaint, who would assess, admit, discharge, or send them back to the ED generalist, in a redundant system. A "procedure of anticipated taking charge" was introduced in period X. It allowed the triage nurse to start standardized diagnostic and therapeutic procedures before physician's assessment in case of patients presenting with pre-determined signs and symptoms, e.g., COVID-19.

Part of the surgical sector was flexibly converted into an ICU in all 3 pandemic periods. Conversion was rarely needed during period Z, and as in-flux to the hospitals was decreasing, the regional government encouraged to avoid conversion and to keep a fully functional surgical sector to make up for the operations missed during 2020.

A Bed Manager Team (BMT) was introduced in period X, albeit becoming fully functional only during period Y – as authors FF, RS, and MC reported – when a structured team was included with a bed manager and 2 fixed co-workers with administrative backgrounds, and a room designated as office. The BMT held constant relationships with internal wards, the ambulance transport system, neighboring district hospitals, and collaborating nursing houses.

Authors FF, RS, and MC reported that admission to the wards of COVID-19 patients in period X did not follow a standardized managerial strategy. Patients were admitted to wards with different medical focus, and specialists moved around the hospital to visit them. COVID-19 wards with interdisciplinary teams were created starting from period Y. They hosted individuals with different leading pathologies but with concomitant COVID-19 infection.

The hospital never changed criteria for admission to wards in period X and Y. Only in period Z were some low-acuity patients were managed as outpatients or at home after standardization of COVID-19 therapies.

A palliation protocol was shared on the hospital intranet during period X. In period Y, the Week Surgery Department was converted into COVID-19 palliative care unit, and a dedicated team was created. Protocols via the intranet became standard again during period Z.

Supplies

The Crisis Unit (CU) started a quantitative assessment of needs followed by two-way research on the market and through the Italian regional governance in period X. Middle and long-term requirements for subsequent periods were calculated based on consumed supply quantities during period X. Once the national and international health care supply chain crisis improved between period X and Y,[13] supplies were stockpiled to ensure autonomy of at least 2 months. Authors FF, RS, and MC reported that guidelines on the reuse of materials were never produced by governing authorities. Reallocation of material to and from the ED was regulated by the BMT starting in period Y. Rationalization failed during period X, as clear guidelines were missing. From period Y onwards, supplies were rationed once their use became clearer against an adequate risk-benefit evaluation, and they were shared across the C-ED and the NC-ED according to needs.

System

The best possible standards of care were maintained throughout the pandemic and in none of the pandemic periods did the CU decide to review ethical principles to limit care, nor did the Italian regional or local government enforce care-limiting guidelines.

External communication was through the local health regulatory agency, operational issues were handled by Sant'Anna's health directors, and operational units' directors oversaw production processes. Smartphones were distributed to the C-ED, the NC-ED, the BMT (1 to each ward), and radio communication was introduced between departments. These communication systems became fully effective in period Y.

External coordination with the dispatch-center improved in period Y after introduction of the EUOL© ("Emergenza-Urgenza Online") informatic software. On the EUOL©, the dispatch center received live updated information on crowding levels of each ED of the region, and ED staff could manually signal issues in accepting new patients.

A new coordination center for the transfer of acute patients within the network of the 18 regional hub hospitals and the "Regional Agency for Emergency" was introduced between period X and Y which led to an increase of patients' transfer.

Relationship Between KPI Changes and Surge Response Strategies

Retrospective analysis of Sant'Anna's actions triggered by the COVID-19 surge showed that 8 of the 22 action items proposed in the HSPRI for crisis capacity were adopted in period X (see Table 4). Eight were implemented before period Y and 1 was introduced in period Z. This sums up to a total of 17 out of 22 actions items introduced. Five action items were not introduced at Sant'Anna, namely: adjusting staff to acuity as needed, the introduction of a palliative care team in the ED, the re-use of

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Table 4. Triggers and action items for staff, space, supplies, and system during crisis capacity activation identified by the Hospital Surge Preparedness and Response Index (HSPRI), compared with key performance indicators (KPIs) modification across the considered periods (A, B, X, Y, and Z)

Period				X	Y	Z
STAFF	Step-up staffing with staff that do not normally provide similar patient care			Yes	Yes	Yes
	Use a tiered staffing model			Yes	Yes	Yes
	Adjust staff to ratios or acuity as needed			No	No	No
	Begin structured onboarding of volunteers			Yes	Yes	Yes
SPACE	Create on site space in non-patient care areas			Yes[a]	Yes	Yes
	Prepare facility adjacent and alternate care/triage areas			No	Yes	Yes
	Expand critical care areas into monitored and other units			Yes	Yes	Yes[b]
	Reduce non-emergency services to focus staff and space on acute care			Yes	Yes	Yes[c]
	Leverage adjacent and alternative care/triage areas			No	Yes	Yes
	Load balance patients across other hospitals/regionally			No	Yes	Yes
	Manage low-acuity patients as outpatients and change criteria for admission to inpatient units			No	No	Yes[d]
	Perform active palliative care team outreach in ED			No	No	No
	Assure that patients are directed to the most appropriate unit for care based on their condition			No	Yes	Yes
SUPPLIES	Re-use			No	No	No
	Reallocate			No	Yes	Yes
	Ration			No	Yes	Yes
SYSTEM	Maintain best possible standard of care given resource constraints			Yes	Yes	Yes
	Load balance to internal and *external* hospital systems to balance staffing and space impacts			No	Yes	Yes
	Publicly communicate and acknowledge crisis conditions (specific to resource deficit) at facility, coalition/region, public, political levels			Yes	Yes	Yes
	Share resources intra and inter facility/system level			No	Yes	Yes
	Provide guidance on care rationing facility / region / state			No	No	No
	Consult / triage team prepared to make care-limiting decisions as required and inform best practices for other rationing decisions			No	No	No
Period		A	B	X	Y	Z
KPIS	Mean LOS (minutes)	383	406	407	470	460
	Mean TPIA (minutes)	182	201	74	128	178
	Left without-being seen rate (%)	15	17	7.6	8.2	13.4

[a]New spaces were not fully functional nor were they respecting safety standards
[b]Only rarely needed / used
[c]Only partial reduction of elective surgery
[d]COVID-19 patients were increasingly handled as outpatients
This table shows the progress of implementation of action items identified during crisis capacity activation across the pandemic periods X, Y, and Z as proposed by the Hospital Surge Preparedness and Response Index (HSPRI), and it puts them in relation to fluctuations of the selected key performance indicators (KPIs). For comparison, the KPIs for control periods A and B are presented at the bottom of the table. Control / pre-pandemic periods: A (March-May 2019), B (October-December 2019). Pandemic periods: X (March-May 2020), Y (October-December 2020), and Z (March-May 2021). LOS: length of stay. TPIA: time-to-physician initial assessment. LWBS: Left-without being seen.

supplies, the use of official guidelines on rationing, and the imposition of care-limiting decisions. The mean LOS and mean TPIA increased across the 3 pandemic periods, both of which were lowest during X. The LWBS rate increased from X and Y to period Z. According to this study's definition, this corresponds to a decrease of ED performance across the pandemic.

Limitations

As a retrospective study the HSPRI did not guide the actions taken by the CU or the CCT. Thus, by applying the HSPRI actions, this study omitted assessment of other surge response actions, which may be relevant modifiers of performance. Similarly, potential external modifiers and confounding factors, e.g., the advent of vaccines or health-seeking behaviors have not been considered. Most qualitative data was obtained with open-ended meetings conducted after the end of the pandemic which may have decreased data accuracy, although initially based on analysis of contemporaneously written and implemented protocols and plans. Cross-comparison and further meetings were needed to reduce potential error. External validity of this study's findings is compromised by the single-center, retrospective study design. Nevertheless, given the nature of the disaster, a prospective study would have been impossible to design. Finally, this study was not able to assess the impact of individual action items on KPIs and no causal relationship can be inferred.

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Discussion

EDs are on the front line of the management of the surge of patients during a pandemic. This places pressure to maintain care while managing system wide delays due to the lack of adequate preparedness to the pandemic surge.[14] Therefore, it is relevant for EDs to develop strategies to expand surge capacity and capability, defined in terms of staff, supplies, structures, and systems,[15,16] this latter including command and control, communication, coordination, continuity of operations, and community infrastructure.[16–17]

At Sant'Anna hospital's ED, TPIA and LWBS recorded an initial improvement in the first pandemic period (X) followed by a reverse trend to pre-pandemic levels. However, an improvement in performance throughout the pandemic after an initial drop was expected as the ED learnt to cope with the surge, given knowledge on surge response actions.[18,19] The fluctuation in COVID-19 patient volume seems to have influenced TPIA. While Como was at the periphery of the pandemic's epicenter in period X, patients reached 6-fold increase in the Province in period Y. Furthermore, many individuals with pressing conditions who would have accessed the ED in 2019 reportedly preferred to avoid crowded Eds, especially in period X, for fear of infection and after appeals not to use ED.[20] As few patients visited the ED in period X, ED staff managed efficiently and adequately.

TPIA worsened as patient volumes increased as did LWBS rates, commonly associated with prolonged wait times.[21] Patient volume is a variable external to an HCF and it belongs to the input category of the input-throughput-output model of an ED.[22] Input components (e.g., disease incidence and pre-hospital infrastructure) have been commonly omitted from performance computation as it is difficult for an ED to control, and are generally considered the responsibility of other healthcare agencies.[23] Factors internal to the hospitals that influence throughput and output of patients have always received most of the attention.[10] However, adjustment of internal factors alone has paradoxically proven insufficient to improve performance.[23] Taken together, these findings strongly support the claim warranted by the CHEST Consensus[24] that hospitals and health care institutions should apply a holistic approach when planning surge response action that considers both internal and external factors as relevant in improving performance.

KPIs worsened throughout the study periods despite interventions. However, increase in LOS and in TPIA in the C-ED dampened as more surge response actions were implemented in period Y and Z. Implemented actions may have buffered an otherwise catastrophic decrease of performance, especially for the C-ED. This studies results differ from findings from the USA and South Korea, where LOS increased progressively as the pandemic unfolded.[25,26] There are some possibilities for this observation, as surge response actions and indicators need to be evaluated in light of the local context.[27,24] In Como, the CU and the CCT had round tables with key hospital stakeholders and adjusted response actions on a daily basis. Local governance met decisions that were in contrast with regional directives on some occasions. Finally, external factors may have influenced KPIs, e.g., vaccinations, a call to which the Italian population responded rapidly.[28]

The HSPRI provided to be a useful retrospective framework for this study to highlight viable action items to guide the HCF in its strategic decisions based on COVID-19 triggers. Although the degree of impact of each action item could not be calculated, it seems that there is no single surge response action which can strongly modify performance. ED performance at Sant'Anna' worsened throughout the pandemic; however, this decline slowed during the Y and Z period. Many action items were retrospectively found to be implemented before, during, and after period Y, the most difficult for the catchment area served by the Sant'Anna' in terms of patients, and a drastic change in performance was never recorded. Instead, KPIs that changed specific to Sant'Anna were slow and progressive, likely influenced by many factors. As corroborated in another study,[29] it seems that the isolated implementation of single action items does not have an adequate impact to sustain performance, but it is the combination of interventions on various ED processes, which involve all 4 strata of surge capacity, i.e., spaces, staff, supplies, and systems, that can significantly sustain performance during a pandemic surge, and it is advisable for HCF leaders to focus on a cross-sectional distribution of resources.

In this study, KPIs specific for Sant'Anna, such as LOS, TPIA and LWBS rate, were a viable method to keep track of ED performance during the COVID-19 pandemic. Nevertheless, they were not sufficient to provide an exhaustive representation of the system's function. It is impossible for HCF leaders to keep track of all possible data[30] as there is no set of indicators able to comprehensively assess the effects of a surge.[10] However, a synthesis of many performance metrics in few KPIs scaled to the local needs and the structure of an HCF that considers both internal and external factors would reduce invested work and potential cost. Furthermore, selection of KPIs that consider the differences and complexity of each ED-community system is critical to ensure accurate and precise performance evaluation.[31] Therefore, while further research is still required to identify KPIs applicable to all HCFs, it is advisable for hospital mangers to investigate which of the many identified KPIs best fit with the local reality and to efficiently keep track of the local and regional variables that potentially influence them.

Conclusions

After this retrospective study, the HSPRI has demonstrated value as a tool for a hospital staff to be actively utilized during an emerging infectious disease pandemic, as a framework to identify KPI triggers, and to formulate actions to pre-pandemic care or ameliorate the deterioration of care during the pandemic.

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References

1. **Parotto E**, **Lamberti-Castronuovo A**, **Censi V**, et al. Exploring Italian healthcare facilities response to COVID-19 pandemic: lessons learned from the Italian Response to COVID-19 initiative. *Front Public Health*. Published online 2023.
2. **Pusinelli R**, **Soccio M.** Piano Aziendale Di Governo Del Sovraffollamento e Iperafflusso in Pronto Soccorso. Archive of Sant'Anna Hospital in Como, Italy. Accessed November 15, 2020. Published 2020.
3. Personal correspondence with head of Crisis Unit at Sant'Anna Hospital in San Fermo della Battaglia, Como. March 2022.
4. **Dwinell L**, **Andersen M.** A California hospital's response to COVID-19: From a ripple to a tsunami warning. *Crit Care Nurse.* 2020;**40**(60):1–16.
5. **Perlini S**, **Canevari F**, **Cortesi S**, et al. Emergency department and out-of-hospital emergency system (112—AREU 118) integrated response to Coronavirus Disease 2019 in a Northern Italy centre. *Intern Emerg Med.* 2020; **15**(5):825–833. doi:10.1007/s11739-020-02390-4.
6. **Thomasian NM**, **Madad S**, **Hick JL**, et al. Hospital surge preparedness and response index. *Disaster Med Public Health Prep.* 2021;**15**:398–401. doi: 10.1017/dmp.2021.190.
7. **Thomasian NM**, **Madad S**, **Hick JL**, **Ranney ML**, **Biddinger PD** Hospital Surge Preparedness and Response Index. *Disaster Med Public Health Prep*. 2021 Jun;**15**(3):398–401. doi: 10.1017/dmp.2021.190. PMID: 34311795.
8. Why are healthcare performance measurements important? IBM.com. Published 2022. Accessed October 21, 2022. https://www.ibm.com/topics/healthcare-performance-measurements.
9. **Charney RL**, **Armbrecht ES**, **Kennedy BR**, et al. Pandemic influenza extension areas in an urban pediatric hospital. *Prehosp Disaster Med.* 2012;**27**(1): 75–80. doi:10.1017/S1049023X12000301.
10. **Etu EE**, **Monplaisir L**, **Aguwa C**, et al. Identifying indicators influencing emergency department performance during a medical surge: a consensus-based modified fuzzy Delphi approach. *PLoS One.* 2022;**17**(4):1–16. doi: 10.1371/journal.pone.0265101.
11. **Kanter RK**, **Moran JR.** Pediatric hospital and intensive care unit capacity in regional disasters: expanding capacity by altering standards of care. *Pediatrics.* 2007;**119**(1):94–100. doi:10.1542/peds.2006-1586.
12. **Morton MJ**, **Deaugustinis ML**, **Velasquez CA**, et al. Developments in surge research priorities: a systematic review of the literature following the Academic Emergency Medicine Consensus Conference, 2007-2015. *Acad Emerg Med.* 2015;**22**(11):1235–1252. doi:10.1111/acem.12815.
13. **Spieske A**, **Gebhardt M**, **Kopyto M**, et al. Improving resilience of the healthcare supply chain in a pandemic: evidence from Europe during the COVID-19 crisis. J Purch Supply Manag. 2022;January:100748. doi:10.1016/j.pursup.2022.100748.
14. **Carrington MA**, **Ranse J**, **Hammad K.** The impact of disasters on emergency department resources: review against the Sendai framework for disaster risk reduction 2015–2030. *Australas Emerg Care.* 2021;**24**(1):55–60. doi:10.1016/j.auec.2020.09.003.
15. **Barbisch DF**, **Koenig KL**. Understanding surge capacity: essential elements. *Acad Emerg Med.* 2006;**13**(11):1098–1102. doi:10.1197/j.aem.2006.06.041.
16. **Berge LR**. Health care emergency management: principles and practice. *JAMA*. 2011;**305**(2). doi:10.1001/jama.2010.1982.
17. **Hick JL**, **Koenig KL**, **Barbisch D**, et al. Surge capacity concepts for healthcare facilities: The CO-S-TR model for initial incident assessment. *Disaster Med Public Health Prep.* 2008;**2**(SUPPL.1):51–57. doi:10.1097/DMP.0b013e31817fffe8.
18. **Whiteside T**, **Kane E**, **Aljohani B**, et al. Redesigning emergency department operations amidst a viral pandemic. *Am J Emerg Med.* 2020;**38**(7):1448–1453. doi:10.1016/j.ajem.2020.04.032.
19. **Klein MG**, **Cheng CJ**, **Lii E**, et al. COVID-19 models for hospital surge capacity planning: a systematic review. Disaster Med Public Health Prep. Published online 2020:1–8. doi:10.1017/dmp.2020.332.
20. **Garrafa E**, **Levaggi R**, **Miniaci R**, et al. Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information. *Health Policy.* 2020;**124**(January):1333–1339. doi:10.1016/j.healthpol.2020.10.006.
21. **Bolandifar E**, **DeHoratius N**, **Olsen T.** Modeling abandonment behavior among patients. Eur J Oper Res. Published online 2022. doi:10.1016/j.ejor.2022.08.023.
22. **Mumma BE**, **McCue JY**, **Li CS**, **Holmes JF**. Effects of emergency department expansion on emergency department patient flow. *Acad Emerg Med.* 2014;**21**(5):504–509. doi:10.1111/acem.12366.
23. **Kenny JF**, **Chang BC**, **Hemmert KC**. Factors affecting emergency department crowding. *Emerg Med Clin North Am.* 2020;**38**(3):573–587. doi: 10.1016/j.emc.2020.04.001.
24. **Hick JL**, **Einav S**, **Hanfling D**, et al. Surge capacity principles: care of the critically ill and injured during pandemics and disasters: CHEST consensus statement. *Chest.* 2014;**146**:e1S–e16S. doi:10.1378/chest.14-0733.
25. **Lucero A**, **Sokol K**, **Hyun J**, et al. Worsening of emergency department length of stay during the COVID-19 pandemic. *J Am Coll Emerg Physicians Open.* 2021;**2**(3):1–8. doi:10.1002/emp2.12489.
26. **Chun SY**, **Kim HJ**, **Kim HB**. The effect of COVID-19 pandemic on the length of stay and outcomes in the emergency department. *Clin Exp Emerg Med.* 2022;**9**(2):128–133. doi:10.15441/ceem.21.058.
27. **Veillard J**, **Champagne F**, **Klazinga N**, et al. A performance assessment framework for hospitals: the WHO regional office for Europe PATH project. *Int J Qual Health Care.* 2005;**17**(6):487–496. doi:10.1093/intqhc/mzi072.
28. **Mathieu E**, **Ritchie H**, **Rodes-Guirao L**, **Appel C**, **Gavrilov D**, **Giattino C**, **Hasell J**, **Macdonald B**, **Dattani S**, **Beltekian D**, **Ortiz-Ospina E**, **Max Roser**. Coronavirus (COVID-19) vaccinations. 2020. Published online at OurWorldinData.org. https://ourworldindata.org/covid-vaccinations [Online Resource].
29. **Leung AK**, **Whatley SD**, **Gao D**, et al. Impact of process improvements on measures of emergency department efficiency. *Can J Emerg Med.* 2017; **19**(2):96–105. doi:10.1017/cem.2016.382.
30. **Sørup CM**, **Jacobsen P**, **Forberg JL**. Evaluation of emergency department performance: a systematic review on recommended performance and quality-in-care measures. *Scand J Trauma Resusc Emerg Med.* 2013;**21**(1). doi:10.1186/1757-7241-21-62.
31. **Austin EE**, **Blakely B**, **Tufanaru C**, et al. Strategies to measure and improve emergency department performance: a scoping review. *Scand J Trauma Resusc Emerg Med.* 2020;**28**(1):1–14. doi:10.1186/s13049-020-00749-2.