Remodelling of a regional emergency hub in response to the COVID-19 outbreak in Emilia-Romagna

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ABSTRACT

Emilia-Romagna was one of the most affected Italian regions during the COVID-19 outbreak in February 2020. We describe here the profound regional, provincial and municipal changes in response to the COVID-19 pandemic, to cope with the numbers of patients presenting with COVID-19 illness, as well as coping with the ongoing need to care for patients presenting with non-COVID-19 emergencies. We focus on the structural and functional changes in one particular hospital within the city of Bologna, the regional capital, which acted as the central emergency hub for time-sensitive pathologies for the province of Bologna. Finally, we present the admissions profile to our emergency department in relation to the massive increase of infected patients observed in our region as well as the organisational response to prepare for the second wave of the pandemic.

BACKGROUND

On 21st of February 2020, the appearance of the novel coronavirus 2019 (SARS-CoV-2) was recognised in Italy. Immediately, all the Italian regional health systems were required to prepare for a mass inflow of patients infected with SARS-CoV-2, presenting with either the coronavirus syndrome (COVID-19) or with other emergencies unrelated to the coronavirus. Emilia-Romagna was one of the most significantly affected regions with two main outbreaks: one in the western part of the region, involving the province of Piacenza, and the other one in the eastern part involving the province of Rimini (figure 1).

The central provinces of Emilia-Romagna, Bologna, Modena and Ferrara were initially less involved from the outbreak, consequently they were able to promptly buffer the overload of patients from the most affected provinces by receiving critical and non-critical patients through secondary transfers.

Bologna, within the province of Bologna, is the capital city of the Emilia-Romagna region. It is served by two tertiary referral hospitals, both having an emergency department (ED): Sant’Orsola Malpighi, the academic-university medical centre and the Maggiore Hospital Carlo Alberto Pizzardi, the area level I trauma and stroke centre. The urban area includes two further hospitals without EDs: Bellaria Hospital, the hub for elective neurology and neurosurgery; and Rizzoli Hospital, which is entirely dedicated to orthopaedic pathology.

Finally, two district general hospitals, Bentivoglio and Bazzano, located, respectively, 20 and 25 km far from the city centre, with their own spoke EDs, complete the picture of the Bologna metropolitan area hospital network.

To cope with a planned significant increase in capacity across the central provinces, the traditional organisation of hospitals and care pathways was completely reorganised as described below.

THE REORGANISATION OF THE BOLOGNA URBAN AREA HOSPITALS AND MEDICAL SERVICES

Hospital network response

The hospital network described above was rapidly remodelled following a hub-and-spoke concept, a multilevel organisation where all healthcare facilities within a region are involved in the care of patients according to their capabilities and resources, that was already adopted for the local trauma and stroke networks. Since the number of potentially infected patients needing hospitalisation or intensive care was not predictable at the beginning of the pandemic, this model was thought to potentially allow a flexible number of beds using the local resources, as well as allowing an adequate level of care on the basis of the patients’ needs, and even to limit the overcrowding of major hospitals. The coordination of the hospital network response was devolved to a regional task force made up of a multispecialty expert panel and the medical directors of the hospitals involved. Figure 2 synthesises the geography and functions of the hospitals in the Bologna area after hospital network remodelling.

Hub (central) hospitals

Maggiore and Sant’Orsola Hospitals were used to create surge capacity for patients with high-complexity COVID-19 and without COVID-19 for both emergencies and specialist programmes (cardiac surgery, transplants).

The Maggiore Hospital was chosen alongside the Sant’Orsola Hospital, as having one of the two EDs for the Bologna province, receiving not only emergencies from the province but specifically those emergencies with time-sensitive pathologies (trauma, stroke, myocardial infarction and out-of-hospital cardiac arrest (OHCA)) for both patients with COVID-19 and without COVID-19. All minor surgeries were discontinued in the whole province,
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allowing the Maggiore Hospital to maintain emergency surgery for the whole area.

Sant’Orsola-Malpighi University Hospital mainly dedicated its activity to patients with COVID-19 by increasing the intensive care unit (ICU) bed capacity for patients with COVID-19, creating high dependency units (HDUs), ICUs and dedicated wards; however, due to the complexity of this hospital, that hosts also cardiac surgery, transplant units and other specialties, some units were maintained and developed their own internal pathways for infected patients. In particular, the cardiac surgery unit became the provincial extracorporeal membrane oxygenation referral centre.

**Spoke (peripheral) hospitals**

The ED of the Bentivoglio Hospital was closed with both the Bentivoglio and Bellaria Hospitals being converted into COVID-19 hospitals in order to create surge capacity for patients with low-complexity COVID-19 with respiratory failure but without other organ dysfunctions.

These hospitals accepted all the patients having either a laboratory-confirmed diagnosis of a positive SARS-CoV-2 swab or an interstitial pneumonia with clinical and radiological features suggestive of COVID-19; and after an infectious diseases consultant assessment by means of secondary transfer from hub hospitals, Bentivoglio Hospital’s ED was closed (figure 2).

Bazzano Hospital’s ED was also closed and the hospital was entirely dedicated to low-complexity clean (non-COVID) patients, who were accepted only as secondary transfers. Local population was informed of the closure of the EDs by an extensive information campaign and was asked to refer to their general practitioner by phone for minor disturbances and to call the emergency medical services (EMS) for major disturbances rather than self-presenting to the EDs.

Since ED admissions were mainly managed from territorial EMS during COVID-19 pandemic, no patients self-presented to closed EDs during this period.

Rizzoli Hospital continued to function as pure orthopaedic hospital with internal separate pathways maintaining only urgent activity with admissions after secondary transfers.

With this reorganisation, the two hub hospitals accepted all the emergencies of the city, then low-complexity patients requiring admission were transferred to COVID-19 or non-COVID-19 peripheral spoke hospitals.

All major trauma patients, all patients with suspected stroke or acute myocardial infarction, and all OHCAs were centralised to Maggiore Hospital that functioned as the emergency hub, thus creating a COVID-19-suspected path and a CLEAN path for the incoming patients.

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**Figure 2** Bologna province geography and hospitals in the hub-and-spoke configuration. Ambulance and helicopter symbols refer to emergency departments receptive for EMS, the lung icon refers to the ECMO centre. AMI, acute myocardial infarction; ECMO, extracorporeal membrane oxygenation; EMS, emergency medical services; ICU, intensive care unit.

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The Maggiore Hospital: the central emergency hub hospital

Maggiore Carlo Alberto Pizzardi is a 927-bed hospital, it also includes the Emergency Medical Services Dispatch Centre and the local helicopter emergency medical system (HEMS) base covering a 2.5 million-inhabitant area. The hospital receives an average 800 major traumas per year, (350 requiring ICU), 350 acute myocardial infarctions needing primary angioplasty (about a half of total events, the other half is managed by Sant’Orsola-Malpighi Hospital), 180 OHCA’s and 1200 patients who had an acute stroke.

The ED includes an emergency medicine ward with 40 beds and the critical care area, that is located on the same floor, equipped with a 9-bed mixed ICU involved in the management of complex post-surgical patients from 12 operating rooms and medical patients from the rest of the hospital wards, and an 11-bed emergency-trauma ICU that only manages patients admitted from the ED. The total flow of the two ICUs exceeds 1000 patients per year. A medical HDU unit with nine beds, an eight-bed cardiac ICU, a neonatal-ICU and a stroke unit complete the picture of Maggiore’s critical care environments.

As a consequence of the hospital network remodelling, in addition to all major trauma, acute stroke, acute myocardial infarction and OHCA cases, all other non-traumatic emergency surgery, neurosurgery and neuroradiology procedures were diverted to Maggiore Hospital. The profound remodelling of all the environments from prehospital emergency to critical care is described below (online supplemental file 1).

Helicopter emergency medical system

From the beginning of COVID-19 outbreak and the implementation of the quarantine, the number of overall HEMS missions (usually 800 per year) decreased by 80%, mainly because of the reduction of road and work-related accidents. This allowed the use of HEMS for the organisation of secondary transfers of patients with COVID-19 from the overwhelmed hospitals in the western provinces of Emilia-Romagna (see figure 1). HEMS was mainly used to carry the medical teams dedicated to the transfer of patients with COVID-19 to the sending hospital while the transfer to the receiving hospital was via ground ambulances in order to avoid the need for helicopter decontamination at the end of the mission.

Emergency medical services

Similar to the HEMS, the EMS saw an approximate 25% reduction in demand. At the beginning of the epidemic, the dispatch centre triaged the patients between ‘clean’ and ‘suspected’ using clinical criteria (fever, cough, respiratory distress) and epidemiological criteria (recent contact with confirmed COVID-19 cases, journey through Milan region or China), with the help from public health physicians (PHPs) available on call 24 hours/7 days for the discussion of suspected cases.

When COVID-19 clearly became pandemic and the lockdown began in Italy, on 9th of March, all the patients were managed as patients with suspected COVID-19, irrespective of the clinical and epidemiological criteria, therefore PHP counselling was discontinued.

In order to minimise consumption of personal protective equipment (PPE), the EMS was reorganised so that only the operators who necessarily needed to perform manoeuvres would approach the patient wearing full PPE, with other personnel initially remaining at a distance.

In case of suspected high-acuity dispatches, normally managed by medical cars in addition to the dispatched ambulances, the medical cars were dispatched as usual but waited at a distance while the ambulance personnel performed a second field triage in order to establish the effective need of the enhanced care team and to anticipate and plan its possible intervention. In case of cardiac arrest, the approach was changed in order to minimise the risk of aerosol-generating procedures, based on the International Liaison Committee on Resuscitation and European Resuscitation Council suggestions (https://www.erc.edu/covid).

This allowed the correct application of protection strategies in a difficult context such as the prehospital care, and no contagion has been registered among the EMS staff yet.

Potential contamination of ambulances and other EMS vehicles was mitigated by the development of a specific decontamination area for EMS vehicles and the choice of reserving some vehicles purely for patients with COVID-19.

ED of the Maggiore hub hospital

The original structure of the ED included a 12-bed subintensive area, a 3-bed resuscitation bay, 4 consultation rooms for non-critical patients, a non-critical observation area with 12 beds and 2 emergency CT scanners dedicated to trauma and stroke.

At the peak of the pandemic, the ED was admitting an average of 130 patients per day, half of which were suspected for COVID-19 infection, this compared with pre-COVID when we admitted 160 patients per day. This reduction was globally explained by a decrease in terms of trauma-related admissions mainly due to the national quarantine restrictions. Figure 3 depicts the trend in terms of global ED admissions and admissions of patients with suspected COVID-19 in relation to the cumulative number of infected patients in the Bologna province.

Approximately two patients with COVID-19 per day required orotracheal intubation and intensive care; and despite the slight reduction in ED admissions, the number of ICU admissions progressively increased. Since patients with COVID-19 required prolonged periods of mechanical ventilation, the system was rapidly saturated, therefore a second COVID-19 ICU was opened and less critical patients were transferred to spoke ICUs (please refer to the Critical care and operating rooms section for details).

In order to prevent cross infections between infected and non-infected patients, two main pathways were identified in the ED after 10th of March: one for patients with confirmed and suspected COVID-19 receiving all patients with sepsis and respiratory failure, and one for CLEAN patients accessing the ED for other causes such as trauma, OHCA and neurological emergencies.

Each path was developed with its resuscitation bay for critical patients, a subintensive area with monitored beds and an observation non-monitored area for non-critical patients. The resuscitation and subintensive bay for clean patients was created within the orthopaedic emergency area and can be accessed both from general ED and directly from the ambulances’ discharge area, in order to grant a clean path from outside to the clean resuscitation bay. Then, the two emergency CT rooms were functionally divided into a COVID-19 and CLEAN CT scanner.

Figure 4 depicts the functional pathways for the patients with COVID-19 and the CLEAN patients, while table 1 describes the main structural differences.

Criteria for allocation to COVID-19 or non-COVID-19 pathways

Patients with suspected or known COVID-19 preferably accessed the hospital with dedicated ambulances because the population.
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was constantly instructed not to come directly to the hospital in case of suspected symptoms for COVID-19.

A pre-triage tent able to accommodate up to five patients just outside the hospital was created in order to assess the incoming walk-in patients: all the patients with a known positive SARS-CoV-2 swab, fever ≥37.5°C, oxygen saturation <95% in room air, cough, dyspnoea or a reported strict contact with a patient with COVID-19 were directed towards the COVID-19 pathway (fever cut-off from Italian Society of Infectious Diseases guidelines; https://www.simit.org/). An emergency medicine physician was in the tent 24 hours/7 days taking the final decision on patients’ pathway and was able to perform lung ultrasound (US) as further criteria for suspected cases.10 Lung US played a significant role especially for patients with mild symptoms for the evaluation of the effective need for lung CT scan and as an additional tool to decide whether to keep patients in observation or to discharge them home.11 The tent was heated and the average stay per patient was 30 min.

For unconscious or critically ill patients coming in from the field, a key role was played by the prehospital emergency teams: all patients with known COVID-19 and all the suspected cases (eg, unexplained/hypoxic OHCA) were treated in the COVID-19 resuscitation room, therefore, telephone pre-alert by the EMS was crucial to allow the receiving team to prepare for the arrival of patients from the field.12

All the patients admitted to the COVID-19 pathway underwent a nasopharyngeal swab for COVID-19, laboratory examinations and thorax CT, US or chest X-rays and then were evaluated by an infectious diseases specialist, on duty 24 hours/7 days, in order to confirm the pathway allocation, especially for doubtful cases. The swab reporting required from 4 to 24 hours.

In case of negative nasopharyngeal swab but strong clinical or radiological suspicion for COVID-19, another swab was

**Figure 3** Patients’ flow through the emergency department (ED) of the Maggiore Hospital from 1st of February to 30th of November. The light blue shadow refers to total ED attendances for each day, the dark blue line refers to the relative number of ED patients subsequently admitted to a ward, the purple bars refer to the daily ED admissions for suspected COVID-19 cases. The continuous dark purple line refers to the right vertical axis and indicates the cumulative COVID-19-confirmed cases in the Bologna area (data from: https://statistichecoronavirus.it/province-coronavirus-italia/bologna/).

**Figure 4** Maggiore Hospital pathways for patients with COVID-19 and CLEAN patients. The CLEAN pathway is highlighted in green, the COVID-19 pathway is highlighted in red and the hybrid areas are highlighted in blue. EMS, emergency medical services.
obtained and the patients were admitted to COVID-19 wards in side rooms.

Emergency medicine ward reorganisation

The emergency medicine ward was divided into two functional areas (COVID-19 and CLEAN), each with a dedicated access from separate hallways and elevators, and separate isolated rooms were available for patients with COVID-19. These wards had some HDU capacity, and patients admitted there could be treated with both continuous positive airway pressure (CPAP) and non-invasive ventilation (NIV); since these procedures were considered as aerosol generating, health personnel taking care of these patients used level 2 PPE.

A COVID-19 outreach shift covered by an ICU physician was established in order to constantly assess patients with COVID-19 at risk of deterioration needing either oxygen, CPAP or NIV outside the ICU, and eventually upgrade or define ceilings of care. Limitation-of-care decisions were discussed between the ICU, emergency and palliative care physicians for every patient, taking into account not only the principles of clinical appropriateness and proportionality of care, but also the equity and appropriateness of healthcare resources allocation. A document from the Italian Society of Anaesthesia and Intensive Care defined the clinical ethics recommendations for the allocation of intensive care treatments.13 In case of limitation of care decision, the patient’s relatives were informed by phone and the palliative care service was activated.

Critical care and operating rooms

All the non-urgent scheduled surgical activity was suspended14,15 from 9th of March, six operating rooms remained available for non-deferrable surgery and two operating rooms remained available for emergency surgery.

The trauma ICU was converted into a CLEAN ICU in order to accept patients with negative SARS-CoV-2 swab or admitted with diagnoses associated with low COVID-19 risk (eg, traumas, complex post-surgical patients, intracranial haemorrhages). All patients admitted to the CLEAN ICU underwent a SARS-CoV-2 swab from tracheal aspirate at the admission and were treated as potentially infected until negative swab response (4–24 hours).

In case of positive tests these patients were transferred to the COVID-19 ICU.

The former surgical ICU was converted into a COVID-19 ICU with the installation of a negative pressure system for the whole ICU and the installation of a separate room for the donning and doffing of PPE.16 A second COVID-19 ICU was built ex novo in an idle area of the hospital in the period going from 3rd of March to 15th of March, and became operative on 16th of March with 6 beds eventually increasable up to 20 beds. The COVID-19 ICUs initially received critically ill patients from other regional ICUs which were unable to cope with the numbers of patients needing critical care. This continued until local cases began to be admitted. The original COVID-19 ICU managed predominantly patients with COVID-19 with acute respiratory distress syndrome and multiorgan failure, while those patients with COVID-19 with single organ respiratory failure or those requiring weaning were managed in the newly built COVID-19 ICU or transferred out to other ICUs in the spoke hospitals.

Specialistic ICUs and HDU

The specialistic ICUs (cardiac, neonatal and stroke) maintained their original organisation in order to ensure the hospital’s capability to manage the whole city’s time-sensitive pathologies, ensuring isolated beds for patients with COVID-19 who were transferred to appropriate non-intensive areas once monitoring was no longer needed.17 The HDU was converted into a COVID-19 staging area capable of managing both level 2 and level 3 patients at high risk of SARS-CoV-2 infection while waiting for swab’s result or in case of non-availability of beds in the COVID-19 ICU.

SPECIFIC ISSUES

The oxygen pipeline failure

The increased number of admissions of patients with respiratory failure notably increased the oxygen flow demand for the hospital system that reached, at the peak of the crisis, the 80% of the maximum flow available (400 m³/hour). Despite this, the distribution system for the emergency medicine ward experienced a failure due to a massive increase in demand.

The standard oxygen pipeline of the emergency medicine ward can deliver an average of 7 L/min per bed at its maximum capacity. With the increasing number of patients requiring CPAP and NIV, the standard system was not adequate to sustain the high oxygen flow needed for traditional CPAP and NIV devices for all the patients admitted to the emergency medicine ward and oxygen demand rapidly reached 450 L/min, that was the maximum flow deliverable for that area.

In order to ensure this unanticipated oxygen consumption in the emergency medicine ward and to grant the 24-hour supply of liquid medical oxygen, a technical intervention on the pipeline consisting in the installation of a second main pipeline derived...
from the hospital’s high pressure distribution pipeline with its own pressure regulator was performed.

During the technical intervention, which required 7 days, the clinical director switched the CPAP treatment for the patients with COVID-19 from ventilator CPAP with high oxygen flow (around 40 L/min) to CPAP pressure driven often used in prehospital with low oxygen flow rates (around 10 L/min). We had no problem in sourcing the low-flow CPAP masks and no significant events related to patients were recorded during this period.

**Personnel recruitment and PPE**

In order to increase the care capacity of the whole system, it was necessary to recruit highly trained health professionals as intensive care consultants and nurses through new hires (350 health professionals that were added to a total of 8200 units already working at the hospital) and diverting anaesthetic and emergency personnel from peripheral hospitals that suspended their operating room activity (around 300 staff). Senior anaesthesia and intensive care residents were hired and actively involved both in the ICU and in urgent operating room activities. Surgeons and other personnel who reduced their level of activity as a consequence of COVID-19 pandemic were recruited for low-intensity wards after specific training about the criteria and strategies for oxygen therapy and NIV.

Shortage of PPEs and equipment (such as ventilators, helmets, infusion pumps) was a problem shared by all the hospitals involved in the COVID-19 outbreak. Planning, rationalisation of PPE usage and use of spare materials, as well as solidarity initiatives such as fund raising and direct donations, allowed the provision of sufficient PPE as recommended by the WHO. Hospital infection control personnel were involved in the training of all healthcare workers and in continuous vigilance about correct donning, doffing and PPE use with weekly inspections of the COVID-19 wards. No instances of staff being infected due to PPE shortages were recorded.

Psychological support was available for all the personnel who requested it, moreover, thanks to charity donations, accommodations for health personnel far from home or quarantined were rapidly provided.

**DISCUSSION**

In our opinion, the system worked efficiently enough to manage the overwhelming workload of the pandemic: it was able to divert and reallocate resources between hospitals, simultaneously maintaining the ability to care for the reduced numbers of patients with non-COVID-19-related emergencies.

On the contrary, we are prone to think that many issues were challenging and would have deserved more consideration. Specific issues that we found most challenging were:

- The allocation of patients with suspected COVID-19 to COVID-19 or non-COVID-19 pathways was particularly challenging. The more time needed for a swab result, the more difficult this problem becomes; a ’filter zone’ is probably the better solution, ideally with the capacity to allocate level 2 and 3 patients.

- COVID-19 ICU and its bed availability are the cornerstone of COVID-19 management as this is mainly a respiratory pathology with frequent multiorgan involvement. Moreover, ICU nurses and doctors are needed even outside ICU in order to assess, manage and allocate the patients. Thus, a prompt organisation of personnel and devices around ICUs is essential.

- Patient flow between hospitals is crucial to manage resources. An efficient EMS transport system is needed in partnership with the local emergency operations system and ambulance dispatch centre to coordinate regional ground ambulance resources.

- Decision makers of the regional task force during the whole process were the medical directors of the hospitals involved into the COVID-19 network assisted by an expert panel composed of an intensivist, an infectious diseases specialist, a radiologist and an emergency medicine doctor. The regional task force gathered at least once a week or more often if needed during the ascending phase of the pandemic. A regional supervision is needed in order to stay up-to-date with the balance between needs and resources.

**Evolution of the pandemic, subsequent measures and preparation for the second wave**

From 9th of March to 4th of May 2020, the government imposed a national quarantine, restricting the movement of the population except for necessity, work and health circumstances, and mandated the temporary closure of non-essential shops and businesses. This allowed a progressive reduction in the transmission of the SARS-CoV-2 virus, therefore reducing the number of patients requiring hospital admission with the number of infected patients from 21st of April (see figure 3).

Globally, the hub-and-spoke network model granted a rapid and flexible increase in terms of ordinary ward and ICU bed availability but also aiming to grant the adequate level of care specifically needed for each patient while specialist structures were being built.

As a consequence of the reduced need of hospital and ICU COVID-19 beds after the quarantine, the spoke hospitals converted into COVID-19 hospitals progressively returned to their previous functions and the remaining patients with COVID-19 were transferred to newly built COVID-ICUs into the Maggiore and Sant’Orsola Hospitals; this process was completed on the first days of July and now these ICUs are part of the regional COVID-19 intensive care network (see below).

A new COVID-19 intensive care network for the Emilia-Romagna region that now provides a total of 146 ICU beds into six hub hospitals located into four provinces (Parma, Modena, Rimini and Bologna) was established. Therefore, patients with COVID-19 should be centralised to hub hospitals of the COVID-19 network that can provide different levels of care for these patients, while the other hospitals, as well as the wards within COVID-19 hubs that were previously converted into COVID-19 wards, resumed their previous functions for patients without COVID-19.

The COVID-19 intensive care network had the aim to provide a network able to treat patients with COVID-19 without affecting the standard healthcare system at a regional and super regional level, therefore avoiding the need to reduce ordinary activity in case of a second wave.

From October 2020, Italy has been facing the second wave of COVID-19 pandemic, the national real-time index has increased above 1.0 and the National Health System has observed another raise in hospital admissions due to SARS-CoV-2 infection.

Starting from 6th of November 2020, the Italian government has imposed a national nightly curfew (22:00–05:00) together with a partial regional lockdown. The Italian regions were split into three categories (red, orange and yellow) on the basis of a complex evaluation of items including the number of COVID-19 infections and the degree of hospital occupation. In
red—high-risk zones, movements are allowed only for work, health reasons, essential shopping or emergencies, but all non-
essential shops are closed. In the orange—medium-risk regions, people can move freely but cannot leave their home town or city, and shops remain open. In the yellow zone, only the national restrictions apply.19

Emilia-Romagna was initially classified as a yellow region and then switched to the orange zone for 3 weeks. Figure 3 shows the daily number of contagions during the second wave period. Globally, the COVID-19 ICU network was saturated within a month after beginning of the second wave, and with regard to the Bologna metropolitan area, Bentivoglio Hospital was again converted into a spoke COVID-19 hospital. However, the other hospitals of the network were able to keep their original activity; and in the Maggiore Hospital, non-COVID activity is being carried on along with COVID-19 activity thanks to the newly built ICUs, therefore avoiding the non-COVID system paralysis needed during the first wave.

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