

Hospital reengineering against COVID-19 outbreak: 1-month experience of an Italian tertiary care center

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Abstract. – OBJECTIVE: The recent outbreak of SARS-CoV-2 infection in Italy has resulted in a sudden and massive flow of patients into emergency rooms, and a high number of hospitalizations with the need for respiratory isolation. Massive admission of patients to the Policlinico "Agostino Gemelli" Foundation of Rome, Italy, determined the need for reengineering the entire hospital.

MATERIALS AND METHODS: In this article, we consider some of the structural and organizational changes that have been necessary to deal with the emergency, with particular reference to non-intensive medicine wards, and the preventive measures aimed at limiting the spread of SARS-CoV-2 infection among hospital staff and patients themselves.

RESULTS: 577 staff members were subjected to molecular tests in 1-month period and 3.8% of the total were positive. 636 patients admitted to the COVID-19 pathway were included and analyzed: 45.4% were identified as SARS-CoV-2 positive. More SARS-CoV-2 negative patients were discharged in comparison to SARS-CoV-2 positive patients (59% vs. 41%, respectively). On the other hand, more SARS-CoV-2 positive patients were transferred to ICUs in comparison to SARS-CoV-2 negative patients (16% vs. 1%, respectively). Occurrence of death was similar between the two groups, 11% vs. 7%, for SARS-CoV-2 negative and positive patients, respectively. 25% of ≥80 years old SARS-CoV-2 positive patients died during the hospitalization, while death rate was lower in other age groups (5% in 70-79 years old patients and 0% in remaining age groups).

CONCLUSIONS: Rapid hospital reengineering has probably had an impact on the management of patients with and without SARS-CoV-2 infection, and on in-hospital mortality rates over the reporting period.

Key Words:

COVID-19, Coronavirus, Hospital care, Staff protection, Non-Intensive Care, Reengineering.

Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the etiologic agent of the outbreak of 2019 novel coronavirus disease (COVID-19), originating from the city of Wuhan, Hubei Province, China¹. Initially, the Wuhan Municipal Health Committee reported 41 cases of "pneumonia of unknown etiology" to the World Health Organization at the end of December 2019². In a period of 3 months, an outbreak of apparent idiopathic pneumonia had become the COVID-19 pandemic, spread to more than 100 countries around the world³.

To date, Italy is one of the most affected countries, with important repercussions on the health system⁴. Strong containment measures have been adopted by Italian government, as the predicted relevant increase in the number of cases of COVID-19 was expected to exceed quickly the capacity of hospitals to admit affected patients, without taking into account other emergencies^{5,6}. Other undertaken measures have regarded the need of equipment and of trained personnel, as well as the necessity of organizational models based on standard protocols and collaborative networks⁷⁻¹⁰.

The Policlinico “Agostino Gemelli” Foundation of Rome, Italy, developed disease outbreak response measures in coordination with nursing and other allied health staff. The two goals of these measures were to facilitate the care of patients with known or suspected COVID-19, and to reduce the risk of viral transmission to health-care workers and other patients. This article aims to describe the measures taken to address these goals, including identification and set-up of a COVID-19 dedicated hospital pathway, modification of workflow and processes, and management of staff, with particular regards to the non-Intensive Care (non-IC) environment.

Materials and Methods

Reengineering process

The Policlinico “Agostino Gemelli” Foundation of Rome is a tertiary care hospital, the largest in number of beds in Central and Southern Italy and considered one of the best 100 hospitals in the world¹¹.

Facing the pandemic, one of the pivotal aims of our hospital was to protect hospital staff from being infected with the virus. The rapid spread of this new and little-known Coronavirus, the huge influx of patients at a frenetic pace, and the widespread shortage of personal protective equipment (PPE) are factors that can expose frontline health workers to great risk of infection¹². First aim was to increase staff knowledge on how to self-protect from the virus while ensuring the best possible care for patients. This occurred through establishment of training and updating courses on using PPE (recognition of available PPE, choice of PPE necessary according to different care situations, dressing and undressing process, process of disposal or reuse of PPE). These courses were carried out every day, several times a day, to make it possible and simple for all hospital staff involved in the management of SARS-CoV-2 positive or suspected patients to participate these courses.

These interventions were implemented secondary to a double awareness: healthcare personnel represent the population at highest risk of exposure to the infection; moreover, hospital workers can become main carriers of the infection itself, if they are not adequately protected and controlled¹³. For this reason, surveillance measures were also implemented to reduce risk of infection transmitted by infected healthcare personnel. The protection program included performing

nasopharyngeal swabs to hospital staff with fever or respiratory symptoms, or who have been accidentally exposed to COVID-19 affected patients (COVID-patients) without wearing PPE; screening of personnel employed in COVID-19 dedicated wards (COVID-wards) was also included.

Another key aim was to identify patients and staff flow within the hospital, in order to separate departments that could be SARS-CoV-2 contaminated from wards less at risk¹⁴. A dedicated hospital pathway for established or suspected COVID-patients was identified, starting from Emergency Department (ED). Patients with fever or respiratory symptoms have been channeled into a separate flow maintaining preventive isolation procedures.

The Policlinico “Agostino Gemelli” Foundation response to COVID-19 outbreak was a diluted and prolonged emergency plan: in anticipation of massive patients’ influx with established or suspected SARS-CoV-2 infection, 14 new non-IC medical units have been specifically assigned to COVID-patients management. Starting March, this has occurred rapidly and gradually anticipating the increased demand for hospital beds, running up to a total 381 beds intended exclusively for this type of patients (out of around 1500 hospital beds). This was possible thanks to suspension of hospital elective activities (both medical and surgical) with the exception of urgent elective services. Subsequently, we have faced a gradual reduction of COVID-19 related accesses, and inpatient units previously destined for managing COVID-patients have been concordantly reduced (minimum opening length of COVID-unit: 7 days; maximum opening length: 30 days still ongoing) (Figure 1 and Figure 2).

These non-IC COVID-wards were managed by multidisciplinary teams organized *de novo*, and composed of specialists and residents in the following medical disciplines: Internal Medicine (30 consultants and 35 residents), Geriatrics (21 consultants and 7 residents), Gastroenterology (11 consultants and 9 residents), Endocrinology (5 consultants and 9 residents), Rheumatology (6 consultants and 4 residents), Allergology (3 consultants and 3 residents) and Neurology (2 consultants and 2 residents). The mean doctor-to-patient ratio in non-IC COVID-wards was 1/2.2 (min 1/1.5 – max 1/3.1). The aforementioned multidisciplinary teams managed COVID-patients in constant collaboration with on-call colleagues specialized in Infectious Diseases and Pulmonology, and with the Intensive Care Center.

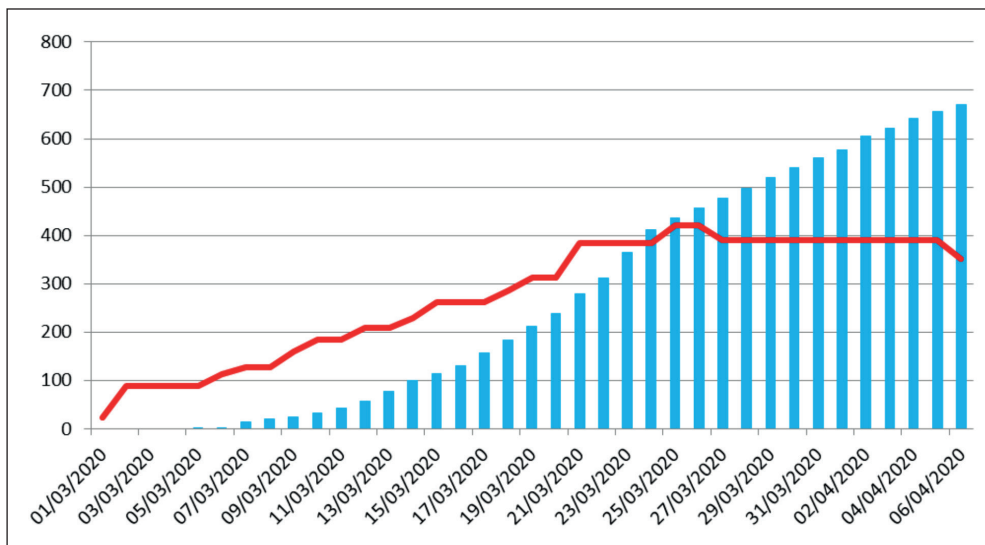


Figure 1. Cumulative COVID-19 pathway admissions (blue columns) and cumulative COVID-19 hospital beds number (red line).

Each multidisciplinary team was coordinated by a team leader, part of the team's doctors. Team leader's tasks were to organize daily duties and to evaluate care quality and criticalities of the team itself. Team leaders meetings have been held every day in order to take stock of the situation and to align teams' health assistance quality (Figure 3).

Furthermore, it has been considered that around 10-20% of COVID-patients are critically ill patients with a possible need for intensive care; ICU stay can be long, with an average duration

of about 10 days¹⁵. This reduces chances of rapid patients discharge or transfer from ICUs, and therefore affects the possibility of accepting new patients. For this reason, the Policlinico "Agostino Gemelli" Foundation ICU beds have been increased by 65%.

In addition, an entire hospital - the Columbus Integrated Center -, which has previously housed some of Internal Medicine, Nephrology, Rheumatology, Gastroenterology and Surgery departments, was converted into a COVID-19 dedicated hospital. This hospital is located a very short

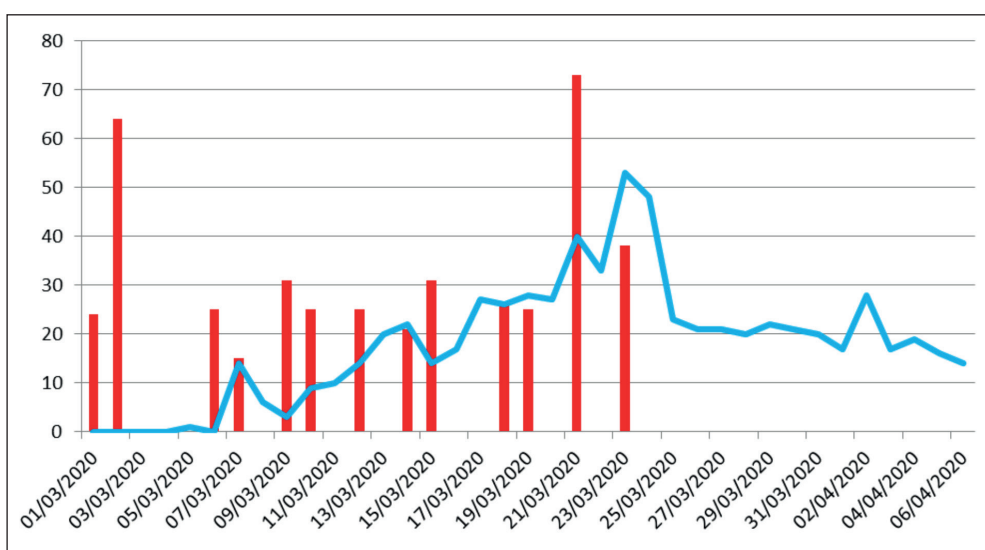


Figure 2. New COVID-19 dedicated hospital beds per day (red columns) and new COVID-19 pathway admissions per day (blue line).



Figure 3. Doctors and Nurses Teams Leaders' daily briefing. Courtesy of Luigi Avantaggiato.

distance from the Policlinico “Agostino Gemelli” Foundation and shares the same ED. On March 16, 2020, an ICU with 21 beds and a non-IC ward with 30 beds were opened; and a week later, a total of 60 IC beds and 150 non-IC beds were available. The completion time was 12 days in total.

As previously mentioned, along with gradual reduction of COVID-19 related accesses, a progressive reduction of units assigned to COVID-patients management has begun, and hospital elective activities, both medical and surgical, have gradually resumed. In order to keep separate pathways and avoid infection spread between SARS-CoV-2 positive and negative patients or hospital staff, it was decided to carry out nasopharyngeal swabs and rapid serological tests for all elective patients, before actual hospitalization. Patients with positive rapid serological test are hospitalized with preventive isolation procedures, pending swabs result. In case of SARS-CoV-2 positive swab, patients are managed in the COVID-path and assessed any discharge based on clinical picture, postponing elective procedure to negative swab or clinical stability.

Results

Regarding the hospital staff protection program, starting March, molecular tests for SARS-CoV-2 infection diagnosis or screening have been carried out according to surveillance program established by Policlinico “Agostino Gemelli” Foundation health management. Therefore, 577 staff members were subjected to molecular tests in 1-month period and 3.8% of the total were positive ($n = 22$). In particular, 1.7% of COVID-pathway staff and 0.35% of non-IC COVID-wards were positive.

On March 7, 2020, the first case of SARS-CoV-2 infection was diagnosed at the Emergency Department of Policlinico “Agostino Gemelli” Foundation. As of April 7, a total of 869 patients were admitted to the COVID-pathway. Analysis was performed retrospectively and last updated on April 16, 2020. We analyzed only patients who were hospitalized in non-IC COVID-wards after Emergency Department (ED) admission. We excluded from the analysis 233 patients who were admitted to other wards (non-COVID wards, surgical wards) or directly to intensive care units (ICUs).

A total of 636 patients were finally included and analyzed. Average age of included patients was 68.3 years. When patients were stratified by age, 29.4% (n=187) were ≥ 80 years old, 24.7% (n=157) were between 70-79 years old, 15.9% (n=101) were between 60-69 years old, 16.8% (n=107) were between 50-59 years old and 13.2% (n=84) were ≤ 50 years old. Males were 61.3% (n=390).

Based on the outcome of two nasal swabs - collected at least 48 hours from each other - a total of 289 patients (45.4%) were identified as SARS-CoV-2 positive. Male patients were found to be positive to SARS-CoV-2 in 55% of cases while 38.2% of women were found positive.

We then analyzed the outcomes of ED admission based on the following five categories: discharge, transfer to non-COVID wards (only for patients with 2 negative nasal swabs, and clinical and radiological picture non-consistent with SARS-CoV-2 infection), transfer to non-IC COVID-wards, transfer to COVID or non-COVID ICUs, and death.

When analyzing all patients included we found that 43% (n= 271) of patients were discharged, 22% (n= 140) were transferred to a non-COVID ward, 17% (n= 106) were transferred to a non-IC COVID-ward, 8% (n= 48) were transferred to ICUs, 8% (n= 19) deceased and 3% (n= 22) were still in progress.

Based on the SARS-CoV-2 status, we found that more SARS-CoV-2 negative patients were discharged in comparison to SARS-CoV-2 positive patients (59% vs. 41%, respectively). On the other hand, we found that more SARS-CoV-2 positive patients were transferred to ICUs in comparison to SARS-CoV-2 negative patients (16% vs. 1%, respectively).

Occurrence of death was similar between the two groups, 11% vs. 7%, for SARS-CoV-2 negative and positive patients, respectively. Up to 62% of patients in the SARS-CoV-2 negative group died in ≤ 4 days after hospital admission.

Hospitalization outcomes were then analyzed only for SARS-CoV-2 positive patients. In this group, discharge occurred in 18% of ≥ 80 years old, 25% of 70-79 years old, 51% of 60-69 years old, 52% of 50-59 years old and 54% of ≤ 50 years old patients. Only 6% of ≥ 80 years old patients positive for SARS-CoV-2 were transferred to ICUs. On the other hand, 25% of ≥ 80 years old SARS-CoV-2 positive patients died during the hospitalization, while death rate was lower in other age groups (5% in 70-79 years old patients and 0% in remaining age groups).

Finally, number of hospitalization days was recorded. For all patients the average number of days of hospitalization was 9. Hospitalization was

longer for SARS-CoV-2 positive in comparison to negative patients (12 vs. 7 days). On average, patients were transferred to ICUs after 3 days (4 days for SARS-CoV-2 positive vs. 2 days for negative patients). Death occurred on average after 5 days from admission (6 days for SARS-CoV-2 positive vs. 4 days for negative patients).

Discussion

In recent months, the COVID-19 pandemic has been posing many challenges to hospital organization and patient care¹⁶. The lack of awareness and training of healthcare professionals, the lack of personal protective equipment (PPE) and the lack of diagnostic tests for healthcare professionals were considered among the main reasons behind the spread of SARS-CoV-2 infection, as reported by Zhou et al¹². In Italy, as of May 1, 2020, more than twenty-one thousand health workers tested positive after real-time reverse transcriptase-polymerase chain reaction (rRT-PCR) assay for SARS-CoV-2, making up 10% of Italian COVID-19 cases¹⁷. It is known that SARS-CoV-2 has a high indoor transmissibility rate and, therefore, patients with no respiratory symptoms have probably propagated the infection to unsuspecting and unprotected health workers within the healthcare environments¹⁸.

Rate of Policlinico "Agostino Gemelli" Foundation staff who tested SARS-CoV-2 positive was low. In particular, only one doctor resulted positive among those who worked in non-ICU COVID-wards (0.6% of medical staff employed in these units). There can be several explanations for this result. First, in Italy the SARS-CoV-2 epidemic has begun to spread from northern regions since February¹⁹; this led to a high level of alert in the city of Rome before first cases have been found in our hospital, secondary to a great awareness of the problem. Second, prevention measures undertaken within the Policlinico "Agostino Gemelli" Foundation were aimed to separate internal routes (COVID and non-COVID pathways) as rigidly as possible from ED access throughout hospitalization, with total separation also of staff assigned to the two different paths. Third, before first cases have been detected and then on a regular basis, entire hospital staff undergone training and updating courses on the process of using PPE (recognition of available PPE, choice of PPE necessary according to the different care situations, process of dressing and undressing, process of disposal or

reuse of PPE). In this regard, we underline that we have never gone short of PPE for managing SARS-CoV-2 positive or suspected patients; inadequate personal protection of health workers was a central problem in areas with a higher infection rate among health professionals¹². Fourth, extensive screening of hospital staff allowed to identify early any infected operator, who has been immediately treated as inpatient or quarantined at home, reducing chance of spreading the infection to patients, visitors or other hospital staff.

Analyzing 1-month data concerning SARS-CoV-2 positive patients, we found that more positive patients were transferred to ICUs in comparison to negative patients. These data might suggest that positive patients require more frequently intensive care management, including advanced ventilation methods. However, it should be considered that usual hospital activities were greatly reduced with an influence also on ICUs admissions.

The mortality rate of COVID-patients was lower than the national average (7.0% vs. 12.7%)¹⁷. This data must be subject to further evaluations, and explanations should be sought carefully through a comparative evaluation of different hospital centers. Among the possible explanations, we can speculate on the non-homogeneous diffusion of this epidemic in Italy, affecting first and most the northern regions and then extending towards the South. This determined greater awareness and higher alert long before first positive patients were found at our hospital; in particular, rapid hospital reengineering processes were implemented. First, the creation of a COVID-19 dedicated path before first COVID-patients were detected. Second, rapid transformation of hospital wards into departments dedicated to management of SARS-CoV-2 positive or suspected patients, with an increasing number of beds available, which made it possible to manage all patients who accessed the ED and needed hospitalization. Third, a multidisciplinary management of COVID-patients: doctors with different medical specialties joined teams taking care of patients who in most cases turned out to be elderly and with multiple comorbidities.

We also found that mortality of Sars-CoV-2 positive patients during the reporting period was lower than mortality of negative patients. We noticed that there has been a sharp drop in ED accesses number of non-COVID patients, probably due to a spread of alleged increase in risk of contagion within healthcare environments, and as consequence of extended lockdown. There was an increase in average clinical condition severity of patients who arrived in ED, while patients with

less serious illness probably decided not to go or postponed the hospital arrival. Moreover, most SARS-CoV-2 negative patients died in the very first days of hospitalization, thus precluding complete diagnostic work-up and, in particular, swab execution, thus potentially underrating the actual number of SARS-CoV-2 positive patients.

The population of infected patients hospitalized into Medical wards is usually heterogeneous²⁰. Patients admitted to non-IC COVID-wards turned out to be highly complex, characterized by advanced age and multiple comorbidities²¹; in several cases, given the poor prognosis, intensive cares have been not indicated even before hospital admission. At Policlinico “Agostino Gemelli” Foundation, multidisciplinary teams have had in charge the complexity of COVID-patients admitted to non-IC wards. Teams’ components were chosen between specialists and residents already employed in medical departments, with high prevalence of internists and geriatricians that usually manage this kind of patients. The favorable doctor-to-patient ratio allowed regular medical rota and safe rest hours for every doctor involved. Moreover, low rate of SARS-CoV-2 infection among hospital staff kept level of stress and emotional involvement low. Beyond the specific medical treatments implemented for COVID-patients, not covered by this article, all the aforementioned aspects regarding COVID-19 management within non-IC wards have probably had an impact on patients’ outcomes. Further studies are needed to evaluate all the variables that affected the above results.

Conclusions

In the hospital setting, preparation for a pandemic involves changing infrastructures and processes, managing hospital staff and planning infection prevention strategies. Policlinico “Agostino Gemelli” Foundation is a highly complex environment with multiple stakeholders including doctors, nurses and technicians. Aligning the interests and concerns of all parties can be a challenge. However, we believe these reengineering measures were necessary to optimize the quality of care provided to COVID-patients and to reduce the risk of viral transmission to hospitalized patients or healthcare professionals. All this was possible thanks to early planning of strategies, to great sense of duty of each operator involved, and above all to resilience skills that allowed rapid adaptation of all the forces involved to exceptional healthcare needs. We hope that our experience may be useful to other hospitals in the event of possible further crises.

Appendix A.

The Authors of the present manuscript are on behalf of **Gemelli Against COVID-19 Clinician Team (GAC-19 CT) Study Group**: **Coordinator**: Gasbarrini Antonio. **Secretary**: Mora Vincenzina. **Teams Leaders**: Armuzzi Alessandro, Biscetti Federico, Franceschi Francesco, Gambassi Giovanni, Garcovich Matteo, Gremese Elisa, Iaconelli Amerigo, Landi Francesco, Montalto Massimo, Pompili Maurizio, Rapaccini Gian Ludovico, Santoliquido Angelo, Tosoni Alberto, Zileri Dal Verme Lorenzo. **Internal Medicine**: Abbate Valeria, Capristo Esmeralda, Cianci Rossella, De Matteis Giuseppe, De Vito Francesco, Feliciani Daniela, Funaro Barbara, Gallo Antonella, Guidone Caterina, Impagnatiello Michele, Marrone Giuseppe, Miele Luca, Montalto Massimo, Nesci Antonio, Nicoletti Alberto, Pizzoferrato Marco, Pizzolante Fabrizio, Ponziani Francesca Romana, Porfidia Angelo, Santoliquido Angelo, Agostini Fabiana, Amato Elena, Antonucci Gabriele, Burzo Livia, Cammà Giulia, Casciaro Antonio Francesco, Cecchini Andrea Leonardo, Costante Federico, D'Addio Stefano, D'Alessandro Alessia, Del Zompo Fabio, Di Gialleonardo Luca, Di Luca Roberta, Iaquineta Angela, Leo Massimo, Liguori Antonio, Macerola Noemi, Mancarella Francesco Antonio, Monti Flavia, Murace Celeste Ambra, Nardella Elisabetta, Paratore Mattia, Pero Erika, Popolla Valentina, Porceddu Enrica, Rossi Raimondo, Rossini Enrica, Rovedi Fabiana, Salvatore Lucia, Santini Paolo, Schiavello Francesca, Sestito Luisa, Stella Leonardo, Talerico Rossella, Tarli Claudia. **Geriatrics**: Acampora Nicola, Bellieni Andrea, Brandi Vincenzo, Carfi Angelo, Ciciarello Francesca, Cipriani Maria Camilla, D'Angelo Emanuela, Falsiroli Cinzia, Fusco Domenico, Landi Giovanni, Liperoti Rosa, Lo Monaco Maria Rita, Martis Ilaria, Martone Anna Maria, Marzetti Emanuele,

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Declaration of Competing Interest

The Authors declare they have no conflict of interest.

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