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Impact of the healthcare reorganization of the Local Health Authority services in Rieti (Italy) during the SARS-CoV-2 pandemic

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Abstract

Background. *The need to contain the spread of the SARS-CoV-2 pandemic has forced national and local organizations to define and implement targeted emergency response and management measures. As the knowledge about the infection grew, a wider range of organizational measures were deployed.*
Methods. *This study involves the SARS-CoV-2 infected people managed by the Local Health Authority of Rieti (Italy). Diagnostic test waiting times and hospital admission rates in the Province of Rieti are investigated as the pandemic evolved. Trends were analyzed in relation to the tempora spreading of SARS-CoV-2, to the organizational actions taken by the Local Health Authority of Rieti, and to the deployment of actions across the territory. A municipalities classification of the province of Rieti was conducted after a cluster analysis based on the diagnostic test waiting times and the hospital admission rates.*
Results. *Our findings show a declining trend, thus indicating a possible positive effect of the measures taken to contain the pandemic.*
The cluster analysis of the municipalities of the Province of Rieti makes evident an inhomogeneous geographical distribution of examined parameters (diagnostic test waiting times and the hospital admission rates), demonstrating the capability of Local Health Authority of Rieti to reach even the most disadvantaged areas and implying that the differences are due to the demographical variabilities.
Conclusion. *Despite some limitations, this study outlines the importance of management measures in response of the pandemic. These measures should adapt to social, cultural and geographical nature of the territory involved. The findings of the present study will contribute to the update of further pandemic preparedness plans of the Local Health Authorities.*

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1. Background

On 11 March 2020, the World Health Organization (WHO) declared the novel coronavirus (COVID-19) outbreak a global pandemic (1). The Italian government had also already declared the national lockdown (2), and the Lazio Region had established the first guidelines for the healthcare providers and the public sector personnel, defining the at-home testing and treatment under hospitalization as standard operating procedures (3).

When no ad-hoc therapy is available, measures to prevent the spread of a new pathogen require the interruption of the interhuman transmission. Therefore, in addition to fundamental preventive measures, such as social distancing, wearing face masks, and hand hygiene, the use of screening tests for the population, and particularly contact tracing and quarantine, proved to be the most effective strategies to prevent the SARS-CoV-2 transmission (4-5). The Italian Ministry of Health defines contact tracing as the "... tracing and management of the contacts of a confirmed COVID-19 case, a fundamental public health strategy aimed at containing the current epidemic. The aim of contact tracing is to timely identify secondary cases and prevent further transmission of infection. The identification and management of confirmed COVID-19 contacts allow to rapidly trace and isolate any secondary case and thus to break the chains of transmission ..." (6). The Italian National Institute of Health (ISS) has issued the Report n° 53/2020 on contact tracing which, in addition to providing some general information on the COVID-19 case management, is a useful guide for contact tracers. An effective contact tracing requires a consistent testing capability to reduce waiting times for patients and healthcare providers, by shortening the recommended isolation/quarantine period and supporting the healthcare workers in their contact tracing and transmission prevention activities (7).

As a further containment strategy, on 18 March 2020, Italy's first drive-through testing site was opened in Bologna. Such measure drew on the example of South Korea, the first country to introduce drive-through screening centres based on the previous concepts of point of dispensing for bioterrorism and pandemic influenza (8). An American study has reported that a drive-through testing centre, managed by community paramedics, can prove efficient and effective both for hospital staff and patients (9).

In addition, since 27 December 2020, vaccines have been offering a further protection against COVID-19. An effective mass vaccination campaign was designed and delivered, by prioritising high-risk populations (10-11).

To respond to the complicated international health situation and to comply with the directives of the Italian authorities, the Local Health Authority (ASL) of the Province of Rieti, in the Lazio Region, undertook to ensure and improve the local healthcare services. Located in a mountainous area, the Province of Rieti has 155,000 inhabitants, distributed in numerous small municipalities: health services and healthcare policies have the aim to reach, with the best standard, the whole population of the province.

Thus, this study aims at investigating the impact of the healthcare reorganization implemented by the LHA of the Province of Rieti in terms of (i) elapsed time to diagnose COVID-19 through a swab test in symptomatic patients; (ii) elapsed time to diagnose COVID-19 through a swab test in patients identified through contact-tracing; (iii) overall hospital admission rates or home isolation rates; (iv) mortality ratio. For each of the above measures, we have reported the time trend and any statistically significant differences resulting from the deployment implementation of each action. Reducing the time to reach a diagnosis following the interventions by health authorities has the

goal of improving the clinical outcome of SARS-CoV-2 infection (12). To highlight any positive or negative situations, we have identified the geographical areas with similar trends.

2. Materials and methods

The study drew on two databases extracted from the CVE (Corona-Virus Emergency) platform developed by the Lazio Region to collect the information about SARS-CoV-2-positive subjects provided by the LHAs through the contact tracing activities and the swab testing performed in the private or public laboratories across the region. The platform was constantly updated to improve the quantity and the quality of the data.

From 1st March 2020 to 12th December 2021, the LH of Rieti reported 12,668 COVID-19 patients, of whom we have direct information (age, gender, residence, etc), contact tracing records, past medical history, need for hospitalisation and clinical status.

The study investigated the data available for all patients over the time interval considered: the symptoms onset, the date of the swab test, reason for testing (symptoms or contact tracing), date of test result, place of isolation (hospital or home), date of recovery or death (12-13).

Table 1 illustrates the schedule of the actions deployed by the LHA of Rieti.

We calculated the average time from the symptom onset to the diagnosis for the patients with symptoms, and from the date of contact-tracing to the date of the diagnosis

Table 1 - Schedule of the organizational and health care actions implemented by the Local Health Authority of Rieti in relation to the temporal trend of the pandemic and to the vaccination campaign.

ACTIONS	KEY	DATE
Initial actions: Contact tracing group and testing with personnel belonging to the department of public health service and nasal-oropharyngeal swab test at the clinical core hub (outside the local health authority)	Time 0	01/03/2020
Establishment of proactive nursing care, in-house analysis of the TNF samples, launch of text messaging service with the mayors of the municipalities, launch of text messaging service with the primary care physicians/primary care paediatricians to promote a constant communication with the COVID group and Strategic Direction	a	01/04/2020
Opening of a permanent drive-through swabbing HUBs	b	01/05/2020
Establishment of COVID Active Surveillance, Testing and Contact Tracing	c	01/10/2020
Organization of SPOKE facilities as drive-through clinics at other Local Health Authority departments across the territory (permanent and mobile)	d	27/10/2020
Use of nasopharyngeal swab tests along with molecular tests (nasal and oropharyngeal swabs)	e	02/11/2020
Introduction of a Computerised Management Information System + Reorganization of the COVID group with an increased specialisation	f	16/11/2020
Launching of vaccination campaign: Health Care Workers, Health Care Workers and Residents of Nursing Homes and Assisted Living Facilities	g	28/12/2020
Establishment of Special Departments of Continuing Care (physicians + nurses) to support the home visits of the primary care physicians/ primary care paediatricians	h	01/01/2021
Opening of a vaccination HUB in the north central area and two SPOKE facilities in the north and south area of the province for the vaccination open days	i	08/02/2021
Vaccination Campaign for patients with underlying conditions	j	01/03/2021
Launch of the vaccination campaign for the general populations / Introduction of the monoclonal antibody	k	01/04/2021

for the cases detected through contact tracing. We compared the average onset-to-diagnosis interval during the implementation of the relevant organizational measures with the situation at "Time 0", using the t-test or the Wilcoxon test (if data were not normally distributed) (14).

For the analysis of the hospitalizations, we calculated the relevant percentages. Any association between the actions taken and any hospital admission was analyzed using the chi-square test (14).

On the other hand, we used linear regression models for the trend analysis, using time as an independent variable, and the median times, percentages or ratios as dependent variables (14).

To identify the geographical areas having similar trends, we applied the cluster analysis, using the k-means method (14, 15). The following parameters were used:

- Average days elapsed from symptom onset to the swab testing for the diagnosis of SARS-Cov-2 infection
- Average days elapsed from the moment of contact tracing to the swab testing for the people intercepted through contact-tracing
- Days elapsed from the day of the swab test to recovery/death
- Overall hospital admission rates

The results from the comparative analysis are considered statically significant if p-value is < 0.05, or marginally significant if p-value is < 0.10, otherwise, statistically non-significant.

All statistical analyses were performed using R 4.0.4.

3. Results

Our sample included the 12,597 citizens of the Province of Rieti who were infected with SARS-CoV-2: 6,387 (50,7%) were females, and 5,176 (41,3%) were over 50. The LHA of Rieti has performed - in the period of interest - 156,517 swabs for COVID-19. Out of them, 23,437 were collected in home-care setting, the remaining were collected at the several drive-throughs of the province.

First, we analyzed the onset-to-diagnosis interval for symptomatic patients (§ 3.1), by calculating the median times for each time interval related to an organizational structure (Table 2), and for each month, highlighting the trends (§ 3.1.1 and § 3.1.2). Second, we analysed the diagnostic waiting times for the subjects detected through contact tracing (§ 3.2), by calculating the median time for each time interval (Table 1), and for each month, calculating its trend (§ 3.2.1 and § 3.2.2). Likewise, we analyzed the hospital admission rates and self-isolation rates (§ 3.3), both by the time of interventional action (Table 1) and by month (§ 3.3.1 and § 3.3.2). Moreover, we also reported on the mortality during the months under analysis (§ 3.4). Finally, we identified the clusters across the territory (§ 3.5).

3.1. Diagnostic waiting times for symptomatic patients

3.1.1. Mean for each action deployed

Table 2 outlines the decrease in the onset-to-diagnosis interval for symptomatic subjects, starting from the time when no targeted action plan was in place to the subsequent introduction of the above actions (Table 1).

3.1.2. Trends over time

Figure 1 outlines the monthly median diagnostic waiting times. It shows the same data along with the information on the different COVID-19 waves (coloured regions) and on the actions taken by the Local Health Authority (vertical dashed lines in the dates reported in Table 1). The trend shows a statistically significant decline ($p<0.01$), which was not affected by the COVID-19 waves.

Table 2 - Median times from the symptom onset to the diagnostic swab test for symptomatic patients, trend by actions deployed by the Local Health Authority in Rieti: comparison between the medians for the reference period and the median for time 0.

Actions deployed	Median times (days)	p-value
Time 0	7.75	
a	5.00	n.s.
a+b	4.75	n.s.
a+b+c	3.76	n.s.
a+b+c+d	4.27	n.s.
a+b+c+d+e	4.15	n.s.
a+b+c+d+e+f	3.35	0.09
a+b+c+d+e+f+g	3.09	n.s.
a+b+c+d+e+f+g+h	3.56	n.s.
a+b+c+d+e+f+g+h+i	3.47	n.s.
a+b+c+d+e+f+g+h+i+j	3.19	0.09
a+b+c+d+e+f+g+h+i+j+k	3.08	0.09

To explain the meaning of "a" to "k", see Table 1

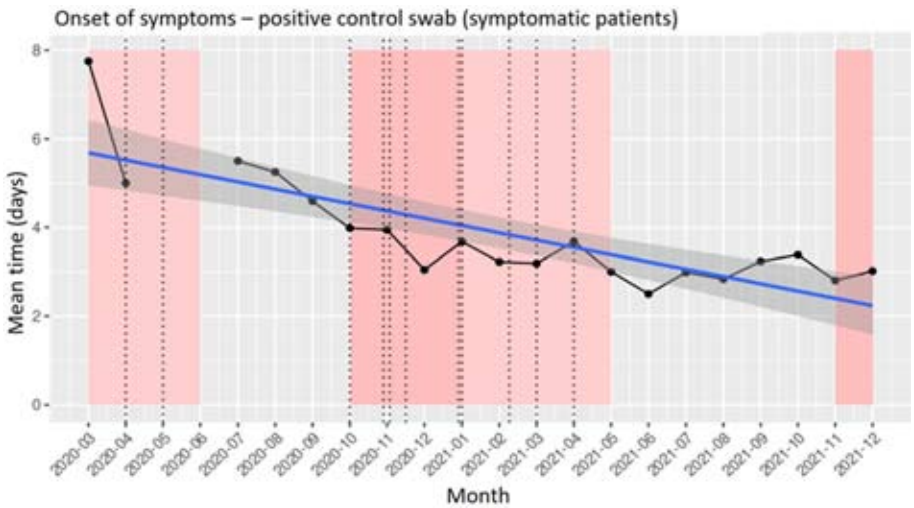

Figure 1 - Trend of the monthly median diagnostic waiting times, where the blue line is the linear regression (R2=0.65, β=-0.16), the shaded regions represent the IC 95%, the vertical dashed lines are the actions taken by the Local Health Authority in Rieti (see Table 1), the red regions highlight the various waves.

3.2. Diagnostic waiting times for patients identified through contact tracing

3.2.1. Mean for each action deployed

Table 3 illustrates the reduction in the diagnostic waiting times for the subjects detected through contact tracing, starting from the time when no targeted action plan was in place to the subsequent introduction of the above actions.

3.2.2. Trends over time

Figure 2 reports the monthly median diagnostic waiting times. It shows the same

Table 3 - Median times from the sampling following the contact tracing to the diagnostic swab test for the subjects enrolled with contact tracing, trend by actions deployed by the Local Health Authority in Rieti: comparison between the medians for the reference period and the median for time 0.

Actions deployed	Median time (days)	p-value
Time 0	3.36	
a	2.54	n.s.
a+b	2.30	n.s.
a+b+c	2.71	n.s.
a+b+c+d	2.75	n.s.
a+b+c+d+e	3.77	n.s.
a+b+c+d+e+f	2.57	n.s.
a+b+c+d+e+f+g	2.05	n.s.
a+b+c+d+e+f+g+h	3.26	n.s.
a+b+c+d+e+f+g+h+i	2.97	n.s.
a+b+c+d+e+f+g+h+i+j	2.42	n.s.
a+b+c+d+e+f+g+h+i+j+k	2.22	n.s.

To explain the meaning of "a" to "k", see Table 1

data along with the information on the different waves (coloured areas) and the actions taken by the Local Health Authority (vertical dashed lines). The trend shows a statistically significant decline (p=0.02), with a significant rebound during the second and third wave.

3.3. Hospitalisation

3.3.1. Hospital admission rates for each action deployed

Table 4 shows the decrease in the overall hospital admission rates, starting from the time when no targeted action plan was in

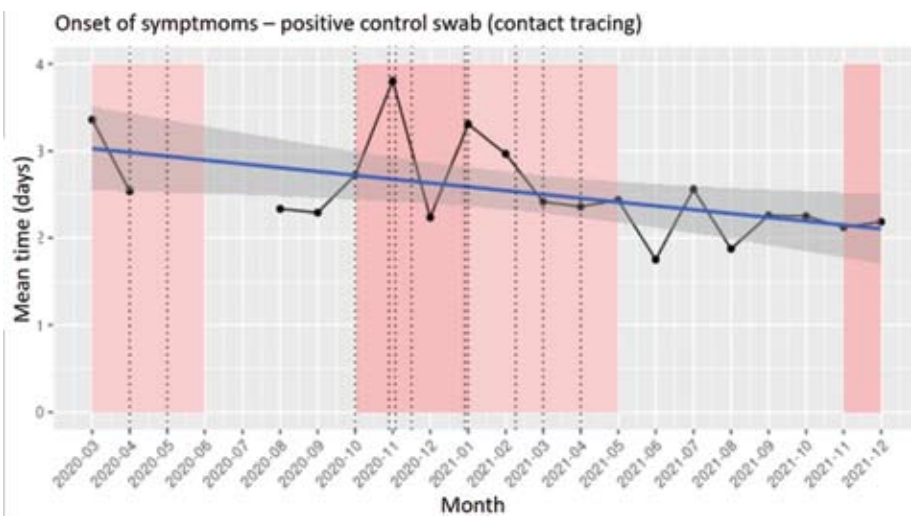

Figure 2 - Monthly trend, the blue line is the linear regression (R^2=0.27, β=-0.04), the vertical dashed lines are the actions deployed by the Local Health Authority in Rieti (see Table 1), the red regions highlight the different waves (see above)

Table 4 - Overall hospitalization rates, trend by actions taken by the Local Health Authority in Rieti, comparison with time 0

Actions deployed	Hospital admission rates	p-value
Time 0	0.16 %	
a	0.29 %	0.003
a+b	0.13 %	n.s.
a+b+c	0.06 %	< 0.001
a+b+c+d	0.10 %	0.06
a+b+c+d+e	0.09 %	0.004
a+b+c+d+e+f	0.07 %	< 0.001
a+b+c+d+e+f+g	0.05 %	< 0.001
a+b+c+d+e+f+g+h	0.08 %	< 0.001
a+b+c+d+e+f+g+h+i	0.06 %	< 0.001
a+b+c+d+e+f+g+h+i+j	0.07 %	< 0.001
a+b+c+d+e+f+g+h+i+j+k	0.05 %	< 0.001

To explain the meaning of "a" to "k", see Table 1

place to the subsequent introduction of the above actions.

3.3.2. Trends over time

Figure 3 summarizes the monthly overall rates of hospitalized and home-isolated patients. It shows the same data regarding only the hospitalization rates along with the information on the different waves (coloured regions) and the actions taken by the Local Health Authority (vertical dashed lines). The trend shows a statistically significant decline ($p<0.01$), characterized by an abnormal trend during the first wave and in June 2021.

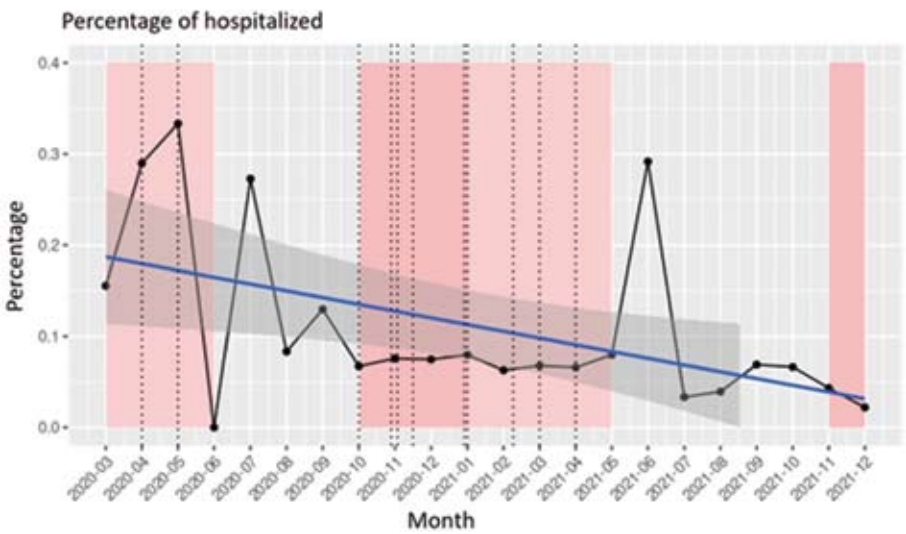

Figure 3 - Monthly trend, the blue line is the linear regression ($R2=0.25$, $\beta=-0.007$), the vertical dashed lines are the actions deployed by the Local Health Authority in Rieti (see Table 1), the red regions highlight the different waves (see above)

3.4. Mortality analysis

Figure 4 depicts the raw mortality ratio (x 1,000 inhabitants) during the period under analysis. The decreasing trend (-0.004430 per month) is not statistically significant. On the other hand, the analysis of the percentage of deaths among all positive patients (Figure 4) shows a statistically significant decreasing trend (-0.24% per month) (p=0.0263).

3.5. Cluster analysis

Out of the 73 municipalities in the Province of Rieti, only 53 were included in this analysis. The other 20 municipalities were discarded, due to the low number of cases among the inhabitants (<20 cases).

Each municipality was measured based on the following parameters:

- *gistm_cs* is the median number of days from the symptom onset to the swab test (for the diagnosis of symptomatic subjects),
- *gistm_ct* is the median number of days from contact-tracing to the swab test (for the diagnosis through contact-tracing),
- *gtg* is the median number of days from the diagnostic swab test to recovery/death, and
- *posp* is the overall hospital admission rates.

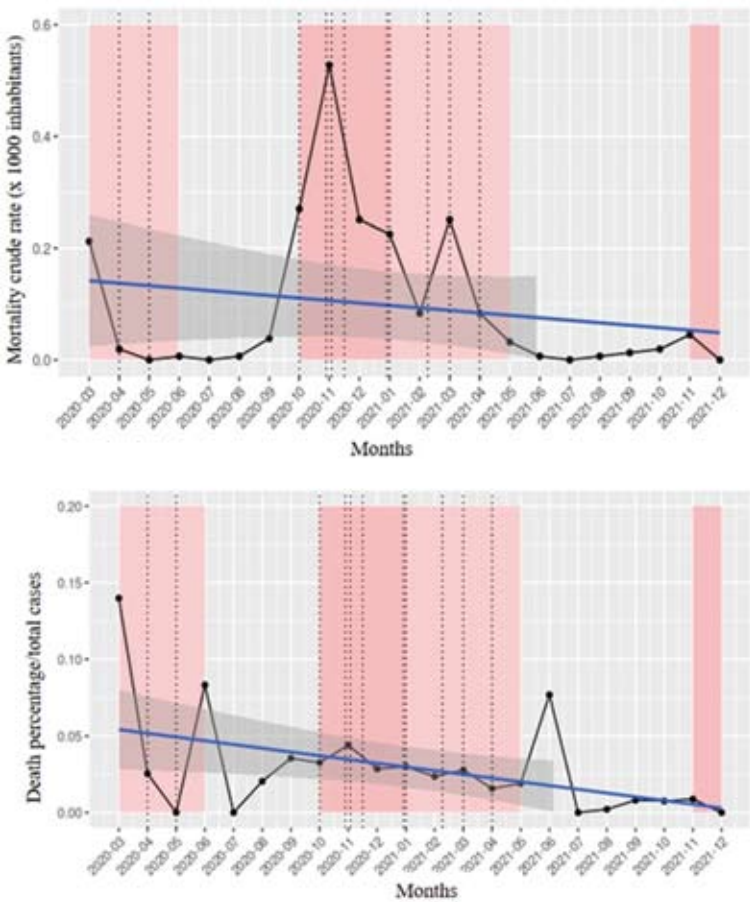

Figure 4 - The double Figure depicts (a) the mortality crude rate per 1,000 inhabitants and (b) the fatality rate (deaths/all positive patients)

Table 5 - Values of the centroid for each cluster

	gistm_cs	gistm_ct	gtg	posp
Cluster 1	3.44	0.68	32.54	0.067
Cluster 2	3.72	2.76	21.29	0.066
Cluster 3	3.56	1.59	25.18	0.066

Using the above parameters, we sought to allocate the municipalities to three clusters to reduce the distance of each municipality from the centroid of each cluster.

Table 5 shows the parameters of the centroid of each cluster.

Cluster 1 is characterized by shorter median diagnostic wait times, particularly for diagnosis through contact tracing, with extended median recovery times. Cluster 2 shows longer diagnostic wait times for the diagnosis through contact tracing, on the other hand the median time to recovery was shorter. Cluster 3 falls between the first two clusters; indeed, the median wait times and the median recovery times show intermediate values. The overall hospital admission rates do not show any relevant difference among the three clusters.

Figure 5 reports the municipalities partitioned into each cluster as a graph.

4. Discussion and conclusions

The four parameters analyzed (i.e., diagnostic wait time for symptomatic patients, diagnostic wait time for patients identified through contact tracing, hospital admissions rates, crude mortality rates and

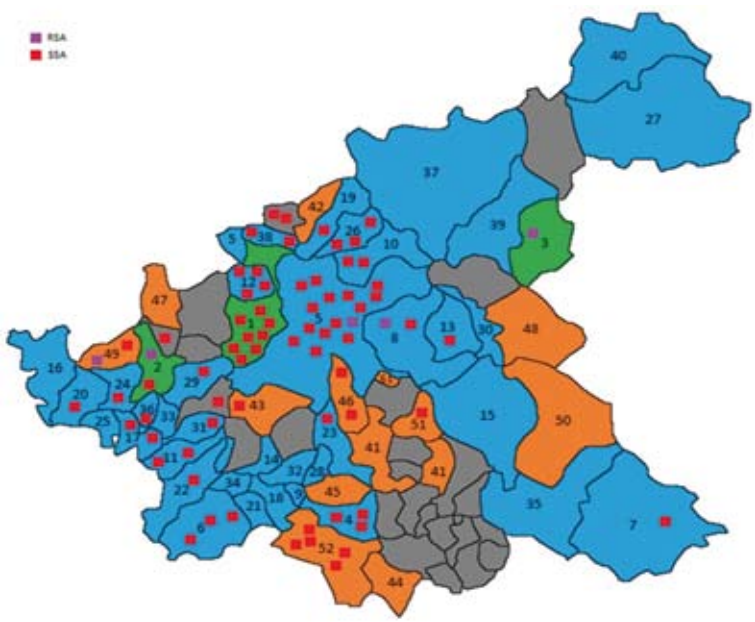

Figure 5 - Map of the municipalities in the province of Rieti partitioned into three clusters. The municipalities highlighted in grey were not included in the study. The Nursing Homes (SSA) and Assisted Living Facilities (RSA) operated in the province are also highlighted.

fatality rates) show a decreasing trend, which suggests the effectiveness of the LHA of Rieti in dominating and addressing the unprecedented healthcare demand due to the sudden outbreak of COVID-19 pandemic.

For symptomatic subjects, the curve does not show any fluctuations associated with the different pandemic waves. On the other hand, the reduction in the median diagnostic wait times was marginally significant in November 2020, probably due to the healthcare reorganization introduced on 1st October 2020 and further developed on 16th November 2020 with the implementation of the computerised contact tracing management system and the improved knowledge of the healthcare providers.

The downward trend for the patients identified through contact tracing is characterized by a lower slope compared with the symptomatic patients, as the median diagnostic wait times for cases identified through contact tracing show increased fluctuations, concurrent with the second and third pandemic wave. Patients experienced longer median wait time as daily case numbers increased and manual contact tracing is "a challenging, labour intensive and time-consuming activity" (16). Consequently, contact tracing effectiveness decreases, causing significant delays in tracing high-risk contacts and therefore in being tested.

The overall hospital admission rates showed a sharp decline at the end of the first waves, from March to May 2020. Such high values at the beginning of the pandemic may have been a result of the lack of adequate knowledge of the disease and of the emergence of sudden coronavirus hotspots within nursing homes. Thus, in order to manage the high number of infected cases, hospital admissions surged. In June and July 2020, the province of Rieti was declared free of COVID-19, with a drop also in the hospital admission rates.

In the second half of July, the trend reversed, due to the emergence of two clusters of cases, one of which was identified during the last few days of the month following the hospital admission. This cluster is highlighted by the curve in Figure 3, which shows a peak value against the absolute low numbers of hospital admissions.

During the second and third wave, and at the beginning of the fourth wave, in autumn 2021, the hospital admission rates dropped, due to various concurrent factors, such as: 1) improved medical and nursing home care enhanced by the collaboration with the primary care physicians and primary care pediatricians; 2) a timely and effective vaccination campaign first foused on high-risk populations and then on other groups in compliance with the national directives (17, 18); 3) the use of monoclonal antibody therapy as an outpatient treatment for COVID-19 positive subjects identified by primary care physicians and referred to the LHA (19).

Similarly to July 2020, June 2021 appears to be an exception, due to a decrease in the case numbers during the summer. The month is thus characterized by high peak values against the absolute low numbers.

The temporal analysis of the organizational capacity of the LHA of Rieti was complemented by an in-depth spatial analysis to understand the healthcare demands of the municipalities, not only to contain the COVID-19 pandemic, but also to develop new community health services.

The cluster analysis has partitioned the municipalities of the Province into three groups. Cluster 1 consists of three Municipalities, Borbona, Contigliano and Torri in Sabina, characterized by shorter median wait times and by longer median times to recovery. This trend was due to the presence across the territory of nursing homes and assisted living facilities housing seniors with multi-pathologies. Thus, these facilities are constantly monitored through

nasal-oropharyngeal swab tests carried out by the proactive nursing care services. Timely contact tracing is activated in case of infection among staff and residents. On the other hand, the median times to recovery among frail and elderly patients are longer as they are more susceptible to severe COVID-19 infection (20). Cluster 2 includes the most densely populated municipalities: Rieti, Fara in Sabina, Cittaducale and Poggio Mirteto. Despite a better healthcare access (hospital, health district and drive-through clinics), the median diagnostic wait times are longer. The municipalities within this cluster are more densely populated, with a younger population, often of school age, and with a more active social life, which may have caused a delay in the contact tracing activities. The median times to recovery were shorter. Cluster 3, characterized by intermediate values compared with the two Clusters, includes 13 small and medium-sized municipalities, where relatively older adults live in lower-density communities (21).

Figure 5 shows that the three clusters do not seem to have a well-defined geographical distribution across the provincial territory, which highlights the capability of the LHA of Rieti to provide a consistent healthcare service despite the logistics challenges posed by the prevailingly mountainous territory of the Province of Rieti.

5. Limitations

The study has at least three limitations.

The first limitation is that the study is a retrospective analysis of the records retrieved from the database of the Lazio Region, which was developed to collect data aimed at epidemiological studies for a prompt containment of the SARS-CoV-2 transmission. The data quality is thus influenced by the likely scant attention given to the information for research purposes. Therefore, performing in-depth investigations, especially of the first wave of COVID-19, was difficult.

A further limitation is that the hallmarks of the SARS-CoV-2 viruses change and evolve over time. Consequently, the temporal trends might not be entirely referred to the actions deployed, but also to the decreased severity of the disease and to the improved knowledge, especially for the trend in hospital admissions.

Moreover, although the analytical methods have allowed to highlight the relationship between the actions deployed and the trend of the diagnostic and treatment procedure, a more accurate investigation should be conducted to analyze any development and enhancement in the available human and instrumental resources.

The advantages of the study are in the possibility to analyze the data of each recruited subject as they are registered within an application software which keeps track of the management of the preventive actions deployed: contact tracing, case identification, monitoring, locating the place of residence of the infected case. In addition, the software interfaces with the hospital discharge data system and with the emergency department database.

After the worldwide spread of the new pandemic virus, WHO encouraged each Member State and those in charge of public health emergencies to develop a "pandemic plan" divided into the following phases: preparedness, readiness, and response.

The experience gained during the pandemic has highlighted that the effective implementation of the WHO guidelines for pandemic preparedness depends on multiple factors, such as cultural, political, social, and geographical factors as well as on the development of the local healthcare services and the health status of the population.

This study conducted at the LHA of Rieti emphasizes that the recommendations given by the competent authorities should

take into account the relevant political, social, health, demographic, and cultural situations of the country where such rules find application. The findings of the present study will contribute to the update of further pandemic preparedness plans of the Local Health Authorities.

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Riassunto

Impatto della riorganizzazione sanitaria della Azienda Sanitaria Locale di Rieti (Italia) durante la pandemia da SARS-CoV-2

Premessa. La necessità di contrastare la pandemia da SARS-CoV-2 ha impegnato le organizzazioni nazionali e locali a definire misure di contrasto e di gestione articolate e dettagliate. Nel tempo, tali misure sono andate evolvendo sia in termini strettamente organizzativi, che al crescere delle conoscenze sull'infezione.

Metodi. Lo studio prende in esame la popolazione risultata positiva al SARS-CoV-2 e presa in carico dalla Azienda Sanitaria Locale di Rieti (Italy). Lo studio analizza i dati dei tempi necessari per la diagnosi e la percentuale di casi ospedalizzati nella Provincia di Rieti all'evolvere della pandemia.

Nello studio, i trend vengono analizzati in relazione all'andamento nel tempo della diffusione del contagio, e anche messi in relazione ai vari interventi organizzativi adottati dalla Azienda Sanitaria di Rieti, e alla distribuzione territoriale degli interventi. E' stata condotta un'analisi dei cluster che ha classificato i comuni della provincia di Rieti in base ai tempi medi alla diagnosi e al tasso di ospedalizzazione.

Risultati. I risultati mostrano trend in discesa, suggerendo un possibile effetto positivo delle misure adottate nel contenimento della pandemia.

L'analisi dei cluster dei comuni della Provincia di Rieti evidenzia un distribuzione geografica disomogenea dei parametri in esame (tempi medi alla diagnosi, tasso di ospedalizzazione), indicando la capacità della Azienda Sanitaria di Rieti di saper raggiungere anche le zone più disagiate, imputando le differenze alla variabilità demografica fra i comuni.

Conclusioni. Malgrado alcuni limiti, lo studio evidenzia l'importanza dell'implementazione di misure organizzative in risposta alla pandemia che sappiano rispondere alle esigenze sociali, culturali e geografiche del territorio. I risultati dello studio forniscono utili informazioni per la stesura di piani pandemici delle Aziende Sanitarie Locali.

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