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Original paper

The impact of COVID-19 on radiological findings in patients accessing the emergency department: a multicentric study

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Abstract

Purpose: The aim of this multicentric study is to illustrate how the COVID-19 pandemic lockdown affected the workload and outcomes of radiological examinations in emergency radiology.

Material and methods: The exams performed in the radiology departments of 4 Italian hospitals during 3 weeks of the Italian lockdown were retrospectively reviewed and compared to the exams conducted during the same period in 2019. Only exams from the emergency department (ED) were included. Two radiologists from each hospital defined the cases as positive or negative findings, based on independent blind readings of the imaging studies. In the case of differences in the evaluation, consensus was reached amongst them via discussion. Continuous measurements are presented as median and interquartile range, while categorical measurements are presented as frequency and percentage; *p*-values were calculated using the *t*-test, Mann-Whitney test, and the χ^2 test.

Results: There were 745 patients (53% male; 62 years [44-78]) who underwent radiological examinations in 2020 vs. 2623 (52% male; 56 years [35-76]) in 2019 ($p < 0.001$). Furthermore, the total number of ED exams dropped from 3206 (2019) to 939 (2020), with a relative increase of CT examinations from 23% to 33% ($p < 0.001$). The percentage of patients with a positive finding was significantly higher in 2020 (355, 48%) compared to 2019 (684, 26%) ($p < 0.001$).

Conclusions: Our findings show that despite the reduction of emergency radiological examinations, there was a relative increase in the number of positive cases. These significant findings are crucial to ensure better organization of radiology departments and improve patient management during similar health emergencies in the future.

Key words: COVID-19, emergency radiology, emergency department, image findings, epidemiology study.

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Authors' contribution:
A Study design · **B** Data collection · **C** Statistical analysis · **D** Data interpretation · **E** Manuscript preparation · **F** Literature search · **G** Funds collection

Introduction

On 11 March 2020, the WHO declared the coronavirus disease 2019 (COVID-19), caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a global pandemic. At the time of writing, the number of infected people is approximately 70 million in 220 countries, with more than 1,500,000 deaths reported [1]. Since the beginning of the COVID-19 outbreak, radiologists were among the first-in-line to diagnose and assess the severity of this disease [2,3]. To properly address the needs of radiology departments, while allowing them to continue to provide standard health care to non-COVID patients, it has been postulated that the organization and workflow of radiology departments during a pandemic needs to change [4,5].

At the beginning of 2020, the strategy adopted by most countries to contain the spread of the virus and flatten the curve of outbreaks was lockdown. In Italy, one of the first European countries to be hit by the virus, the lockdown measures were introduced on 9 March and were lifted on 4 May 2020 [6]. Enforced by the Italian government, these measures consisted of staying at home, limiting outings to gather essential needs (supermarkets, doctors, etc.), social distancing, and ceasing non-essential activities.

The effects of the COVD-19 pandemic have been studied across different medical fields [7,8]. It has been proven that fewer people were seeking emergency healthcare services during the first wave of the pandemic [9]. Several studies have also investigated how the COVID-19 pandemic affected the workload of radiology departments and emergency departments [10-12]. However, few studies have investigated the characteristics of patients referring to hospitals and the severity of their pathologies [13,14].

It is thus the aim of this multicentric study to investigates the changes in the workload of emergency department (ED) imaging examinations during the pandemic; moreover, this study explores how the lockdown measures influenced the types and results of radiological exams performed in Italian hospitals.

Material and methods

Imaging examinations performed in the radiology departments of 4 Italian hospitals (from 23 March to 12 April 2020, and from 23 March to 12 April 2019) were retrospectively reviewed and compared.

Characteristics of hospitals

All the community hospitals included in this study have a radiology department that, among others, serves the ED. The hospitals had a total annual number of ED visits that ranged from 2000 to 45,000. Furthermore, during the COVID-19 pandemic, they were not converted into COVID-hospitals (those where only COVID-19 patients were admitted and treated, while all the other activities were stopped, including ED). These hospitals are located across 4 different regions of central-south Italy; all of them are equipped with XR equipment, sonography equipment, and at least 1 CT scanner; only 1 hospital has an MRI and is able to perform emergency MRI examinations.

Study population

The local institutional review board approved this retrospective multi-centre study. Written informed consent was waived because of the retrospective nature of the study.

Consecutive patients who underwent imaging examinations during their admission to the ED were retrospectively identified. There was only 1 inclusion criterion: all patients must have undergone at least 1 imaging examination (sonography, CT, MRI, or XR) requested from an ED during the selected period. Exclusion criteria for the imaging examinations were: (a) examination was requested from other departments, (b) outpatients, (c) examination not performed, and (d) additional imaging exams performed during an inpatient stay. The following was then recorded for each patient: baseline characteristics (age and gender), clinical indication for examination, and radiological exams performed (number, types, and outcome). The patient baseline characteristics were obtained from medical records.

Image analysis

Two radiologists (with different years of experience in emergency radiology; 4 years, IQR 2.5-12.5) from each hospital evaluated the exams independently. They rated the exams as either positive or negative based on a blind review of the images, and the correlation between images and findings, and with the clinical indication. We defined a "positive exam" as the presence of an abnormal finding in at least one of the imaging examinations performed on the patient, which was also consistent with the clinical indication. Only for sonography were the accompanying reports also evaluated, because, in Italy, the radiologists performed this exam. If the radiologists differed in their exam ratings, a consensus was reached via discussion. For exams that presented with more than one finding, only one was selected via consensus according to the clinical indication and clinical relevance.

Clinical indications were recorded and organized according to the following main categories: trauma, chest, abdomen, neuro, and miscellaneous. Findings were grouped into 4 main categories: neuro, chest, MSK, and abdomen. Furthermore, a sub-analysis of positive cases according to clinical indication and findings was performed.

Definition of computed tomography findings

To standardize the different radiological findings that were encountered during the review process, a list of the main pathologies, with the corresponding description of findings, was provided to all centres. If one of the reviewers came across a pathology/finding not listed, the new condition was added to the list with the description of the corresponding finding after a joint discussion with each of the centres' principal investigators. All the findings encountered are listed in Table 1.

Table 1. Radiological findings encountered in the selected weeks in 2019 and 2020 organized in categories, modified from Vingiani *et al.* [17]

Category	Image findings	COVID-19 pandemic, *n*	Corresponding period in 2019, *n*
Chest	Consolidation/atelectasis	22	59
	Pleural fluid	17	37
	Consolidation and pleural fluid	18	18
	Ground glass opacities	22	9
	Pulmonary/alveolar oedema	10	21
	Pulmonary embolism	4	5
	Parenchymal lesion	3	4
	Pneumothorax	2	4
	Bleeding/hematoma		2
	Aortic dissection		2
	Foreign body	1	2
Neuro	Haemorrhage	14	21
	Parenchymal lesion	5	12
	Stroke	7	7
	Myelitis	1	1
Abdomen	Ileus	10	21
	Hydronephrosis/urolithiasis	34	43
	Parenchymal lesion	17	15
	Cholecystitis/cholelithiasis	12	13
	Diverticulitis	2	4
	Appendicitis	10	6
	Collection/fluid	6	7
	Perforation	1	5
	Pancreatitis	2	1
	Bowel ischemia	5	1
	Testicular pathology	4	3
	Bleeding/haematoma	4	5
MSK	Fracture	109	331
	Dislocation	10	15
	Fracture dislocation		5
	Limb ischemia	1	2
	Deep vein thrombosis	1	1
	Muscular lesion	1	
	Foreign body		2
Total		355	684

Statistical analysis

Continuous variables were expressed as mean ± SD or median and IQR, while categorical measurements were reported as frequency and percentages. Normal distribution was assessed using the D'Agostino-Pearson test. Cohen's kappa (κ) was used to evaluate inter-observer agreement prior to reaching a consensus. A χ^2 was used to calculate *p*-values for percentage relative values, while Student's *t*-test and the Mann-Whitney test were used to evaluate values with normal and non-normal distributions, respectively. A p-value < 0.05 was considered statistically significant. We used MedCalc (version 19, MedCalc Software, Ostend, Belgium) for all statistical analyses.

Results

The total number of patients included in our analyses was 745 (395 male; 62 years [IQR, 44-78]) in 2020 and 2623 (1364 male; 56 years [IQR, 35-76]) in 2019 (Table 2).

The total number of ED exams dropped from 3206 (2019) to 939 (2020), which corresponds to a reduction of 71%. Furthermore, in 2020 there was a relative increase of CT examinations, both with (57 of 939, 6% vs. 96 of 3206, 3%) and without (255 of 939, 27% vs. 654 of 320, 20%) contrast media ($p < 0.001$). A relative decrease of XR examinations was observed from 69% in 2019 to 60% in 2020 ($p < 0.001$) (Table 3). The total number of sonography examinations was reduced by 73%, while there was no significant difference in its relative percentage during 2019 and 2020 (7% of performed examinations).

The exams performed in 2020 and 2019 showed excellent agreement in the identification of positive exams with a κ = 0.91 (0.88-0.94) and κ = 0.92 (0.90-0.94), respectively. Although the absolute number of patients with positive findings was almost halved in 2020 (48% reduction), the relative percentage was significantly higher in that year (355 of 745, 48%) compared to 2019 (684 of 2623, 26%)

Table 2. Demographics of patients for 2019 and 2020

Parameter		COVID-19 pandemic	Corresponding period in 2019	*p*-values
Number of patients		745	2623	–
Sex, *n* (%)	Male	395 (53)	1364 (52)	0.6
	Female	350 (47)	1259 (48)	0.6
Age, years		62 (IQR, 44-78)	56 (IQR, 35-76)	> 0.001

Table 3. Comparison of imaging exams performed in 2019 and 2020

Imaging exams	Overall number			Percentage		*p*-values
	COVID-19 pandemic	Corresponding period in 2019	Differences, %	COVID-19 pandemic	Corresponding period in 2019	
XR	560	2215	–75	60	69	< 0.001
NCCT	255	654	–61	27	20	< 0.001
CECT	57	96	–41	6	3	< 0.001
US	65	238	–73	7	7	0.65
MRI	2	3	–33	0	0	0.69

XR – plain films, NCCT – computed tomography without intravenous contrast, CECT – computed tomography with intravenous contrast, US – sonography, MRI – magnetic resonance imaging

Table 4. Comp arison of positive findings of radiological exams performed in 2019 and 2020

Findings	Overall number			Percentage		*p*-values
	COVID-19 pandemic, *n*	Corresponding period in 2019, *n*	Differences, %	COVID-19 pandemic	Corresponding period in 2019	
MSK	122	356	–66	34	52	< 0.001
Abdomen	107	124	–14	30	18	< 0.001
Chest	99	163	–39	28	24	0.18
Neuro	27	41	–34	8	6	0.32
Traumatic	132	365	–64	37	53	< 0.001

Table 5. Comparison of clinical indications for radiological exams performed in 2019 and 2020

Clinical indication	Overall number			Percentage		*p*-values
	COVID-19 pandemic, *n*	Corresponding period in 2019, *n*	Differences, %	COVID-19 pandemic	Corresponding period in 2019	
Abdomen	162	400	–60	22	15	< 0.001
Trauma	250	1345	–81	34	51	< 0.001
Neuro	70	243	–71	9	9	0.97
Chest	211	439	–52	28	17	< 0.001
Miscellaneous	6	12	–50	1	0	0.39
No indication	46	184	–75	6	7	0.47

($p < 0.001$). MSK findings were the most encountered in both 2020 (123 of 355, 35%) and 2019 (356 of 684, 52%) even though there was a significant reduction of this kind of findings in 2020 ($p < 0.001$). The second most frequent finding in 2020 was abdominal (107 of 355, 30%), which was increased significantly ($p < 0.001$) compared to 2019 (125 of 684, 18%) (Table 4). During the lockdown, findings consistent with trauma were observed in 132 patients (37% of patients with positive findings) with a significant reduction ($p < 0.001$) compared to 2019 (365 patients, 53%) (Table 4).

Clinical indication was not recorded in 184 (7%) patients in 2019 and 46 (6%) patients in 2020 ($p < 0.47$). Although the most frequent clinical indication for imaging examinations was trauma, in both 2020 and 2019, there was a significant reduction (81%, $p < 0.001$) of this kind of indication in 2020 (248 of 745, 34%) compared to 2019 (1331 of 2623, 51%). The second most frequent clinical indication was thoracic for both 2020 (221 of 534, 28%) and 2019 (439 of 2623, 17%), with a relative increase in 2020 ($p < 0.001$) (Table 5). In 2020 there were 45 imaging exams (40 XR and 5 CT) for suspected COVID-19.

We found that the median age of patients undergoing ED radiological imaging was significantly higher during the COVID-19 lockdown (62 years [IQR, 44-78]) compared to 2019 (56 years [IQR, 35-76]) ($p < 0.001$). Furthermore, the sub-analysis of trauma and non-trauma clinical indications according to the patient's age showed a significantly higher median age for patients with trauma indication in 2020 (57 years [IQR, 40-77]) compared to the one in 2019 (47 years [IQR, 25-68]) ($p < 0.001$), while there were no statistically significant differences in median age for patients with non-trauma indication.

Discussion

At the beginning of 2020, during the COVID-19 pandemic, several countries decided on a general lockdown to flatten the curves of outbreaks and reduce the hospitals' workloads. On 9 March 2020, the Italian government instituted a national lockdown [6]. This study demonstrates that the lockdown measures in Italy reduced the emergency radiology departments' workload, but it also caused a relative increase of positive findings in image examinations of patients coming from the ED.

In a recent study, Shi *et al.* reported an overall decrease of 60% in radiological reports, while the emergency radiological examinations were reduced by 51.8% [15]. In another study, Houshyar *et al.* found that radiology examinations suffered a reduction ranging from 32 to 40% during the first 2 weeks after the shelter-in-place mandate, while trauma-related ED imaging volume decreased only by 30% [12]. We found an overall reduction of EDs imaging volume by 71% and a significant reduction (81%) in trauma-related ED imaging. The observed high-reduction in imaging volume could be explained by Italy's situation: Italy was the first European country to deal with the COVID-19 pandemic, and the death rate in that period was very high. Lazzerini *et al.* reported that parents avoided taking their children to the hospitals because of fear of infection, resulting in a delay in health care [16]. We believe that both lockdown measures and fear of hospitals as a possible contagious site had a direct impact on the ED radiological imaging workload, resulting in an overall reduction in imaging volume. This phenomenon has been observed in previous pandemics; in 2003, during the SARS pandemic, Chang *et al.* described the possible correlation between the pandemic and people's fears of reaching medical services [6]. In a recent study, Parikh *et al.* found that despite the statistically significant volume decrease by each modality and body part, non-contrast chest CT increased ($p = 0.0053$) and non-trauma CT did not show a statistically significant volume change ($p = 0.0633$) [10]. We found a relative increase of CT examinations (with and without contrast media) even though an absolute reduction of 58% was observed in such examinations (vs. 71% of overall volume imaging examination). In the same study, they found that sonography examinations were reduced by 40%; this trend is consistent with our findings [10]. A different study described a relative decrease of sonography examinations from 9.6% to 8.5% ($p < 0.001$) [17]. Our results did not show a relative decrease in sonography examinations, as would be expected; however, there was a significant reduction of 73% in this type of examination, which requires close contact with the patient.

During the COVID-19 lockdown, we found a significant relative increase (from 26% to 48% [$p < 0.001$]) of patients with positive findings. Our results are consistent with a recent study that reported a relative increase of patients with a positive result in 2020 (48%) compared to 2019 (31%) ($p < 0.001$) [18]. They hypothesized that the increase of positive cases can be associated with people's fear of hospitals as a possible contagious site and the delay in health care access. Sun et al. evaluated the impact of COVID-19 on emergency departments in a recent multicentric study and concluded that the COVID-19 outbreak caused a decrease in ED visits but a proportional increase of severe ED visits [14]. Even though we did not investigate the patients' severity of illness, the relative increase of positive findings in the ED imaging examinations is consistent with the literature's findings, showing a more severe condition of patients being admitted to EDs [13,14]. In a recent study, Sharperson *et al.* reviewed all ED visits at a 4-hospital academic health system; they found that the proportion of imaging study reports concluding "no disease" or "no acute disease" decreased from 56.7% to 40.6% [17].

The significantly higher mean age of patients with trauma indication in 2020 in our study is consistent with a previously published study [19]; they attributed these findings to the relative increase of low-energy falls during the lockdown.

We found that the thoracic indication was reduced less than other indications, with a relative increase compared to other indications. These results are consistent with previous studies reporting the smallest declines in non-trauma thoracic imaging [12]. This relative increase of thoracic examinations might be due to the COVID-19 infection; particularly, 45 imaging exams (40 XR and 5 CT) were performed for suspected COVID-19. XR identified findings related to COVID-19 infection in 12 patients vs. 2 identified with CT. The swab for SARS-CoV-2 was positive in all these cases, while in the other 17 cases with a positive swab, XR was negative.

There were some limitations to our study that are worthy of mention. First, there was a relatively short period of investigation (only 3 weeks); despite this, our study was robust with more than 3000 patients included. Second, the results of our study might vary depending on the level of lockdown measures and the level of people's fear to access the hospital. During the study period, there was full compliance with the lockdown measures due to the public's fear of the new virus. Finally, the decision to define a case as positive was based solely on a radiological decision (imaging findings) and not on a clinical evaluation.

Overall, we believe that the results of this study can help better understand how the COVID-19 pandemic, and the corresponding lockdown period, impact the emergency radiology department. The decrease in volume of ED imaging examinations was followed by a relative increase in positive imaging findings. This suggests that radiology departments should plan for a decreased volume but be ready for a higher frequency of positive cases during a pandemic and thus should prepare to better use and allocate the resources of departments, especially when limited in a similar situation.

Conflict of interest

The authors report no conflict of interest.

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