COHORT COMPARATIVE STUDY OF COVID-19 VACCINATED AND NON-VACCINATED PATIENTS DEPENDING ON CT CHEST FINDINGS BETWEEN IRAQI AND JORDANIAN POPULATION

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Since the beginning of the COVID-19 pandemic, it has recorded more than 9 million deaths globally as one of the major health crises of this century. This study aimed to compare chest CT properties of COVID-19 infection in vaccinated and non-vaccinated cases by multi-radiologist readers and to evaluate the radiologist's performance in differentiation between these two conditions.

Materials and Methods. A retrospective study was conducted at the Department of Radiology, Al-Kindy Teaching Hospital, Iraq, and the Department of Radiology, Almaqasid Charity Hospital, Jordon from 1st of March 2021 to 1st of December 2022. Nine hundred fifty-one patients were enrolled in this work (400 Jordanian cases and 551 Iraqi cases). Those were diagnosed with COVID-19, which that proven by both chest CT scans and PCR tests.

Results. All groups were significantly different in terms of mean age (p <0.00001) and sex (p = 0.0036). There was a significant difference among vaccine types utilized (p = 0.0022The most common CT scan finding was GGO in all groups with statistically significant differences (p<0.00001). Concerning grouping of CT scores, the findings reported that the majority of vaccinated cases of both nations were located at and below 50% of CT score severity of COVID-19 without difference (p=0.055), this could be due to the efficacy of vaccination. However, compared non-vaccinated patients from both nations, revealed that most of the cases lie at mid-score and above with no significant difference (p=0.639). When dealing with survival, the mortality, and crude death rate among Iraqi vaccinated cases were better than Iraqi non-vaccinated people. In Jordanian vaccinated cases, the mortality rate was zero. In the univariate model, the severity of COVID-19 was seen in elderly, females, and unvaccinated with ground-glass opacification (GGO) of chest CT scan whereas female gender and non-vaccinated status were significant predictors for death in multivariate analysis.

Conclusion. CT scan score may be suitable to assess COVID-19 severity and outcome. Mean old age, female sex and vaccine types could be predictors of COVID pneumonia. The most common CT scan finding was GGO. CT score threshold in vaccinated cases is lower than in non-vaccinated cases. The mortality and crude death rate among Iraqi vaccinated cases were lower than non-vaccinated people. In Jordanian vaccinated cases, the death rates are lower than non-vaccinated peoples. Female gender and unvaccinated groups are the most predictor factors to poor outcomes of disease. These data can help physicians guide management strategies for COVID-19.

Keywords: COVID-19, CT scan score, score threshold, pneumonia, coronavirus.

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КОГОРТНОЕ СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ ВАКЦИНИРОВАННЫХ И НЕВАКЦИНИРОВАННЫХ ОТ COVID-19 ПАЦИЕНТОВ В ЗАВИСИМОСТИ ОТ РЕЗУЛЬТАТОВ КОМПЬЮТЕРНОЙ ТОМОГРАФИИ ОРГАНОВ ГРУДНОЙ КЛЕТКИ СРЕДИ НАСЕЛЕНИЯ ИРАКА И ИОРДАНИИ

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С начала пандемии COVID-19, ставшей одним из главных кризисов здравоохранения этого столетия, во всем мире было зарегистрировано более 9 миллионов смертей. Целью настоящего исследования было сравнение характеристик КТ-изображений грудной клетки при COVID-19 у вакцинированных и невакцинированных пациентов, проанализированных несколькими специалистами, и оценка эффективности работы врача-рентгенолога в дифференциальной диагностике этих двух состояний.

Материалы и методы. Ретроспективное исследование проводилось в отделении лучевой диагностики учебного госпиталя Аль-Кинди в Ираке и благотворительного госпиталя Альмакасид в Иордании в период с 1 марта 2021 года по 1 декабря 2022 года. В исследование был включен 951 пациент (400 человек из Иордании и 551 человек из Ирака) с ранее диагностированным COVID-19, что было подтверждено как результатами КТ органов грудной клетки, так и ПЦР-тестами.

Результаты. Все группы значительно отличались по среднему возрасту (p <0.00001) и полу (p = 0.0036). Также была отмечена значительная разница в использованных типах вакцин (p = 0.0022). Наиболее частой находкой на КТ было выявление участков уплотнения легочной ткани по типу «матового стекла» во всех группах со статистически значимыми различиями (p<0.00001). Относительно анализа КТ-данных, исследование показало, что большинство вакцинированных пациентов обеих наций имели уровень тяжести 50% и ниже без различий (p=0,055), что, возможно, связано с эффективностью вакцинации. Однако сравнение с невакцинированными пациентами из обеих стран показало, что большинство случаев находились на среднем уровне и выше без значительных различий (p=0,639). Показатели смертности и общий коэффициент смертности среди вакцинированных пациентов из Ирака были лучше, чем среди невакцинированных пациентов оттуда же. У вакцинированных пациентов из Иордании смертность была нулевой. В одномерной модели тяжесть COVID-19 наблюдалась у пожилых людей, женщин и невакцинированных пациентов с участками уплотнения легочной ткани по типу «матового стекла» при КТ грудной клетки, в то время как женский пол и отсутствие вакцинации были значимыми предикторами смерти в многомерном анализе.

Заключение. Результаты исследования подтверждают, что компьютерная томография может эффективно использоваться для оценки тяжести COVID-19 и прогнозирования его исхода. Средний возраст, пол и статус вакцинации могут служить важными предикторами развития COVID-пневмонии. Наиболее частыми признаками на компьютерной томографии встречались участки уплотнения легочной ткани по типу «матового стекла». Показатели тяжести COVID-19 у вакцинированных лиц были ниже, чем у невакцинированных, и смертность среди вакцинированных пациентов была значительно ниже, чем у невакцинированных. Женский пол и отсутствие вакцинации оказались наиболее существенными факторами, связанными с неблагоприятным исходом заболевания. Полученные данные могут помочь медицинскому сообществу в разработке оптимальных стратегий лечения пациентов с COVID-19.

Ключевые слова: COVID-19, оценка при компьютерной томографии, порог оценки, пневмония, коронавирус.

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Coronavirus (COVID-19) is the pandemic outbreak caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). It started in December 2019 in Wuhan City, China. It killed more than 9 million and affected all lifestyles of humans [1].

Most papers published have investigated the roles of chest computed tomography scans in the detection and management of COVID-19 [2–6]. However, seemingly all authors reported low specificity and high sensitivity of CT scans due to the similarity in the radiological imaging appearance between COVID-19 and other respiratory diseases [7–9].

Sometimes CT scans are used as an additional diagnostic approach simultaneously in COVID-19 detection [10], but chest CT scans critically make accurate diagnoses [11].

The features of chest CT scan in COVID-19 are varying. The most common finding is bilateral peripheral ground-glass opacities with or without associated consolidation with organizing pneumonia as morphologic property [12, 13], the unilateral patchy or diffuse ground-glass opacities are also recorded [13].

Radiologists need to distinguish COVID-19 radiological features from other viral infections, and non-infectious reasons of other pneumonia, since they can manifest with similar appearances [7, 8, 14-17].

In early 2022, WHO reported more than ten billion vaccine doses have been utilized worldwide and at the minimum percent of 63.1% globally [18].

In a recent meta-analysis of 51 papers by Zheng et al [19] on the COVID-19 vaccine, they found that vaccine effectiveness vs. infection, hospitalization, admission in ICU, and the mortality rate was 89.1%, 97.2%, 97.4%, and 99%, respectively. The limitations of this analysis are questions about the duration of vaccine effectiveness, regimens, and the requirement for booster doses.

In Arabic nations, such as Jordon and Iraq, as far as we know, no previous studies had yet compared chest CT scan findings to differentiate between COVID-19 and non-COVID-19 pneumonia, and to our knowledge, no studies had assessed the abilities of radiologists to distinguish between these two arms. This study aimed to compare chest CT properties of COVID-19 infection in vaccinated and non-vaccinated cases by multi-radiologist readers and to evaluate the radiologist's performance in differentiation between these two conditions.

Materials and Methods.

Study design and setting.

A retrospective study was conducted at the Department of Radiology, Al-Kindy Teaching Hospital, Iraq, and the Department of Radiology, Almaqasid Charity Hospital, Jordon from the 1st of March 2021 to the 1st of December

Table №1. Variables of study patients.

Variables		Iraqi vaccinated cases (n= 131)	Iraqi non-vaccinated cases (n= 420)	Jordanian vaccinated cases (n=135)	Jordanian non-vaccinated cases (n=265)	P value
Age (years), mean±SD		54.45±16.64	60.87±15.33	57.74±18.69	55.07±16.24	<0.00001*
Sex	Male	84 (64.1)	196 (46.7)	65 (48.1)	143 (53.9)	0.0036#
	Female	47 (35.9)	224 (53.3)	70 (51.9)	122 (46.1)	
Vaccine types	AstraZeneca	21 (16)	-	8 (5.9)	-	0.0022#
	Pfizer	45 (34.4)	-	34 (25.2)	-	
	Sinopharm	65 (49.6)	-	93 (68.9)	-	
CT scan findings	Consolidation (Figure 2, 5)	-	20 (4.7)	35 (25.9)	25 (9.5)	<0.00001#
	GGO (Figure 1, 3, 4)	125 (95.5)	355 (84.5)	90 (66.7)	235 (88.6)	
	Septal thickening	6 (4.5)	10 (2.4)	-	-	
	Tree in bud (Figure 5)	-	35 (8.4)	10 (7.4)	-	
	Effusion	-	-	-	5 (1.9)	
CT score (%), median		17	19	15	17	0.06*

*One-way ANOVA; #chi-square test

2022.

Ethical approval.

The local institutional review board of the Department of Radiology, Al-Kindy Teaching Hospital, and the Department of Radiology, Almaqasid Charity Hospital approved this study with a waiver of informed consent.

Patients.

Nine hundred fifty-one patients were enrolled in this work (400 Jordanian cases and 551 Iraqi cases). Those were diagnosed with COVID-19, which that proven by both chest CT scans and PCR tests.

Data collection.

All CT chest scans were read and reviewed by experienced radiologists to avoid selecting cases without CT scan features of pneumonia. Demographic data were obtained from the medical records of all included patients.

Acquisition of CT Image.

CT protocols of chest scans varied and included a combination of unenhanced, and contrast-enhanced scans. The parameters included a tube voltage of 100 or 120 kVp, a 512 matrix, and a slice thickness of 1.25 mm.

Chest CT scan views and features.

These characteristics were assessed according to the Fleischner Society Glossary of Terms for Thoracic Imaging and RSNA Categories and Favored Diagnoses consensus guidelines for the diagnosis of COVID-19, which included:

• Axial view: assessed as peripheral and peri-broncho-vascular.

• Sagittal or coronal view: assessed as lower and upper.

• Laterality (uni- or bilateral).

• Non–tree-in-bud or tree-in-bud nodules.

• Ground-glass opacities (GGO).

• Consolidation.

• Lymphadenopathy.

• Pleural effusions.

• Cavitation [20-21].

Statistical Analysis

Data were analyzed using Statistical Package for the Social Sciences software (IBM SPSS version 22, Chicago, US). The results

Fig. 1 (Рис. 1)

Fig. 1. CT, lungs, axial slice, non-contrast, lung window.

Peripheral sub-pleural patches of GGO involves about 70% of the lung volume. This 50-years-old male patient, not vaccinated present with 10 days of fever and shortness of breath, PCR was +ve, SpO2 = 70%, his condition is deteriorated and need mechanical ventilation.

Рис. 1. Компьютерная томограмма органов грудной клетки, аксиальный срез, без контрастирования, режим легочного окна.

Визуализируются периферические субплевральные участки уплотнения легочной ткани по типу «матового стекла», охватывающие около 70% объема легких. Мужчина, 50 лет, невакцинированный, поступил с лихорадкой продолжительностью 10 дней и одышкой. Результат полимеразной цепной реакции (ПЦР) был положительным, SpO2 = 70%, его состояние ухудшалось, что потребовало искусственной вентиляции легких.

were presented in tables as frequencies and percentages. The chi-square test was used to compare the variables and one-way ANOVA was used to compare groups. Univariate and multivariate regression analysis (Odds ratio [OR] with 95% confidence interval [CI]) was performed to estimate the independency predictors of mortality in COVID-19. P-value < 0.05 is considered a statistically significant difference.

Results.

In this work, Table №1 shows the variables studied of 951 COVID-19 patients who underwent a CT scan of the chest. All groups were significantly different in terms of mean age (p <0.00001) and sex (p = 0.0036). There was a significant difference among vaccine types utilized (p = 0.0022).

Concerning CT scan findings, the most common finding was GGO (Figure 1, 3 and 4) in all groups with a statistically significant difference (p<0.00001). Regarding the percentage of CT scores, there was no significant difference (p=0.06).

About a grouping of CT scores, the comparison between the Iraqi and Jordanian vaccinated populations is shown in Table №2. The findings reported that the majority of vaccinated cases in both nations were located at and below 50% of CT score severity of COVID-19 without a difference (p=0.055), this could be due to the efficacy of vaccination.

However, Table №3 compared non-vaccinated patients from both nations and revealed that most of the cases lie at mid-score and above with no significant difference (p=0.639).

When deals to survival, the mortality, and crude death rates among Iraqi vaccinated cases were 2.3 per 10000 and 2.2 per 10000, respectively and among Iraqi non-vaccinated people, were 30 per 100000 and 5.2 per 10000. Among Jordanian vaccinated cases, both rates were zero and among Jordanian non-vaccinated cases was 6 per 100000 and 2.3 per 10000 (Table №4). It is clear that these two indicators are related, and the mortality rate in Iraq is higher in the unvaccinated group than in the vaccinated group.

The univariate and multivariate regression analyses are listed in Table 5. In the univariate model, the severity of COVID-19 was seen in elderly, females, and unvaccinated with GGO sign of chest CT scan whereas female gender and non-vaccinated status were significant predictors for death in multivariate model.

Discussion.

All groups were significantly different in terms of mean age and sex. There was a significant difference among vaccine types utilized (p = 0.0022). These are disliked by a retrospective study by Garrana et al [22]. They studied 150 CT scans and found insignificant differences in terms of age, sex, and vaccine types. In Baghdad city, Hassan and co-authors studied chest CT scans of 20 cases with COVID-19 aged 62.1±14.3 years [23].

The most common CT finding was GGO in all groups with statistically significant differences (p<0.00001). Regarding the percentage of CT scores, there was no significant difference (p=0.06). Hassan et al reported ground glass in 85.0% of COVID-19 confirmed cases, crazy paving is present (75.0%), vascular dilatation in (60.0%), bronchiectasis in (55.0%) and subpleural bands in (50.0%) with significant differ

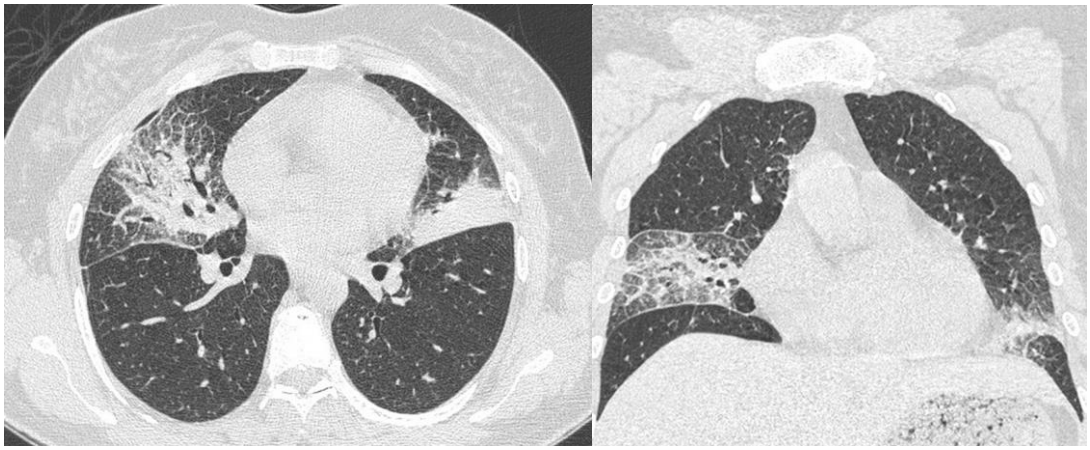

Fig. 2 (Рис. 2)

Fig. 2. CT, lungs, axial and coronal slices, non-contrast, lung window.

Consolidation involving the right middle lobe and lingula with crazy paving appearance of right middle lobe. This 45-years-old non-vaccinated female, SpO2=80%.

Рис. 2. Компьютерная томограмма органов грудной клетки, аксиальный срез, корональная реконструкция, без контрастирования, режим легочного окна.

Визуализируются зоны консолидации в средней доле правого легкого и в язычковых сегментах с признаками «булыжной мостовой» в правой средней доле. Женщина, 45 лет, невакцинированная, SpO2=80%.

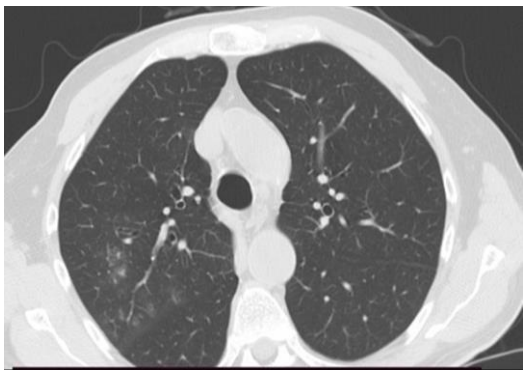

Fig. 3 (Рис. 3)

Fig. 3. CT, lungs, axial slice, non-contrast, lung window.

Small faint foci of GGO involving the anterior and apical segments of the right upper lobe involve about 2% of lung volume. This 55- years-old vaccinated (Pfizer) male, SpO2=99%.

Рис. 3. Компьютерная томограмма органов грудной клетки, аксиальный срез, без контрастирования, режим легочного окна.

Визуализируются небольшие очаги уплотнения легочной ткани по типу «матового стекла» в передних и апикальных сегментах верхней доли правого легкого, занимающие около 2% от объема легкого. Мужчина, 55 лет, вакцинированный (Pfizer), SpO2=99%.

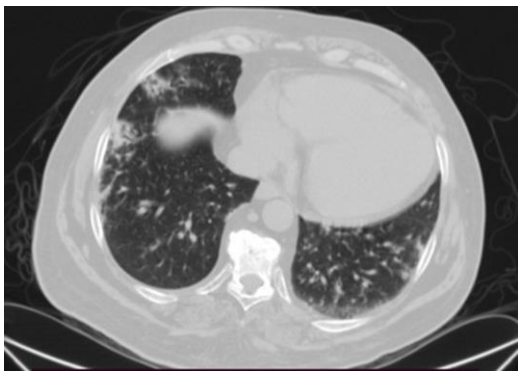

Fig. 4 (Рис. 4)

Fig. 4. CT, lungs, axial slice, non-contrast, lung window.

Patchy areas of GGO involving the peripheral subpleural parts of both lower lobes involving about 7% of the lung volume with septal thickening. PCR was +ve. This 85-years-old vaccinated (Sinopharm) female, SpO2=94 %.

Рис. 4. Компьютерная томограмма органов грудной клетки, аксиальный срез, без контрастирования, режим легочного окна.

Визуализируются локальные участки уплотнения легочной ткани по типу «матового стекла» в периферических субплевральных отделах обеих нижних долей, занимающие около 7% от объема легкого с утолщением плевры. Женщина, 85 лет, ПЦР-положительная, вакцинированная (Sinopharm), SpO2=94 %.

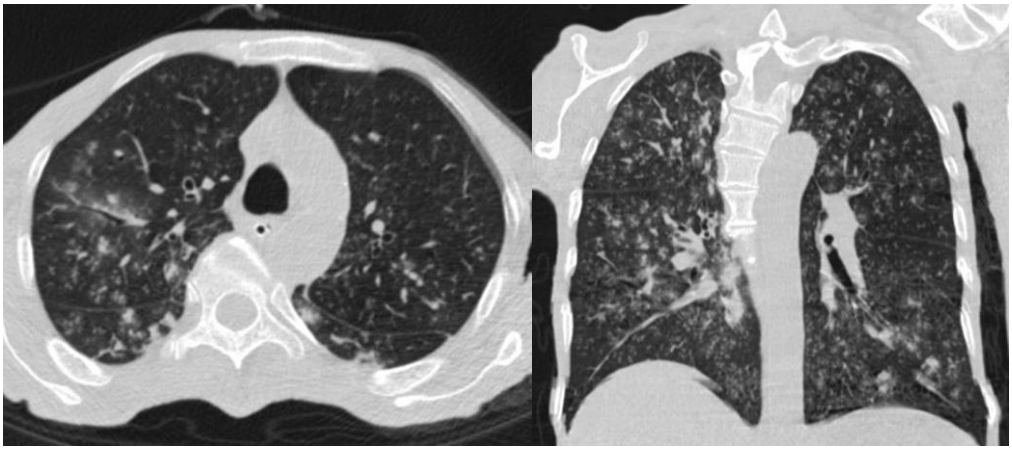

Fig. 5 (Рис. 5)

Fig. 5. CT, lungs, axial and coronal slices, non-contrast, lung window.

Areas of consolidative nodules with tree in buds pattern. PCR was +ve. This 55 years old non-vaccinated male, SpO2=97%.

Рис. 5. Компьютерная томограмма органов грудной клетки, аксиальный срез, корональная реконструкция, без контрастирования, режим легочного окна.

Визуализируются очаги консолидации с наличием симптома «дерево в почках». Мужчина, 55 лет, не-вакцинированный, SpO2=97 %, ПЦР-положительный.

Table №2. CT scan score among vaccinated.

Score (%)	Iraqi vaccinated cases (n= 131)	Jordanian vaccinated cases (n=135)
0	-	-
1-25	97	55
26-50	25	35
51-75	3	-
76-100	-	-
Missing	6	45

Chi-square = 9.238, P=0.055

Table №3. CT scan score among non-vaccinated.

Score (%)	Iraqi non-vaccinated cases (n= 420)	Jordanian non-vaccinated cases (n=265)
0	2	-
1-25	60	45
26-50	210	150
51-75	62	31
76-100	22	14
Missing	64	25

Chi-square = 2.53, P=0.639

ence (P= 0.0001) [23]. Consolidation was present only in (20.0%) of COVID-19 cases while consolidation was recorded in 80/951 cases (8.4%).

GGO, crazy paving alteration, wide vascular dilatation, traction bronchiectasis alteration, subpleural bands, and architecture finding of chest CT are associated with COVID-19 pneumonia, while consolidation is not associated with COVID-19, in conclusion, the chest CT scan can be considered as a preliminary diagnostic tool of COVID-19 cases [22, 23].

uniform healthcare setups, the use of different vaccination types, no standardized definition of fully vaccinated cases, inadequate healthcare resources, heterogeneous populations, and differences in the time interval between vaccination and onset of the outbreak.

Hu et al from China and Sagiraju et al from India reported a lower progression risk to severe disease and a lower mortality rate in vaccinated cases [32, 33]. Several studies in different nations showed these data [34 - 36].

In the univariate model, the severity of

Table №4. Outcome of the study.

Outcome	Iraqi vaccinated cases	Iraqi non-vaccinated cases	Jordanian vaccinated cases	Jordanian non-vaccinated cases
Passed away	3	22	0	6
Survive	128	398	135	259
Mortality rate	2.3 / 10000	30 / 100000	0	6 / 100000
Crude death rate	2.2 / 10000	5.2 / 10000	0	2.3 / 10000

These are supported by Bai et al and Qian et al [24, 25]. Other authors consider consolidation as a characteristic of COVID-19 while others dislike it [26 - 29].

Recently, Fatima and colleagues conducted a prospective observational cohort study in Pakistan [30]. They studied 434 cases with a median age of 61 years, with the majority male gender. Of 434, 193 (44.3%) were vaccinated. In this study, the most vaccinated cases received Sinopharm vaccination (35.7%) same as our sample.

The mortality and crude death rates among Iraqi vaccinated or non-vaccinated people were higher than Jordanian vaccinated cases or non-vaccinated cases. I agree with Fatima et al [30] findings, the worst COVID-19 cases are those who were unvaccinated and might be admitted to ICU, need close monitoring, and may develop severe complications. A surveillance study conducted in Australia demonstrated that around 61800 COVID-19 cases and the vast majority (63.1%) of them were unvaccinated. Most of the patients who died were unvaccinated, and the mortality among vaccinated was 5.8%. Vaccination did decrease the risk of serious infections and death [30, 31]. This could be explained by the lack of electronic healthcare systems programs and non-

COVID-19 was seen in elderly, females, unvaccinated with GGO of chest CT scan whereas female gender and non-vaccinated status were significant predictors for death in multivariate analysis. Fatima et al in the multivariable regression analysis, found that vaccination status was an independent predictor of mortality and unvaccinated patients had statistically significant mortality risk with p-value <0.001 (OR 5.04) [30]. Verma et al and Whittaker et al., revealed the same results regarding vaccination [37, 38].

Fatima et al concluded there is no effective therapy to treat COVID-19 infection [30]. Prevention through vaccination is the hope. The proportion of severe COVID-19, the requirement of ventilatory support, and overall mortality are lower in the vaccinated population.

To achieve a better diagnosis of COVID-19 by chest CT scan, a multileader of experienced radiologists are presenting [22].

In a retrospective study by Garrana et al radiologists showed a poor diagnostic accuracy of 70% for COVID-19 pneumonia and 68% for other pneumonia [22]. Although we found significant differences in the frequencies of CT findings. Awareness of these features might assist radiologists encountering these COVID-

Table №5. Univariate and multivariate regression analysis of the study.

Variable	Odds ratio (OR)	95% CI	Univariate regression	Multivariate regression
Age	3.89	1.25-4.86	0.001	0.69
Female	6.35	4.55-12.56	0.001	0.001
GGO	2.66	1.12-6.35	0.05	0.07
Non-vaccinated	9.12	5.65-18.58	<0.0001	<0.0001

19 cases in daily practice.

Szabo et al concluded that a CT scan score may be suitable to assess the severity of COVID-19 [39]. CT score and chest CT patterns may predict the required ventilation, as well as mortality in COVID-19, which help the staff to guide management strategies in COVID-19, as well as other infections.

Chest CT with scoring is very useful in determining COVID-19 pneumonia detection, also this scoring can help determine disease outcome [39 - 46].

In this study, CT score compared between the Iraqi and Jordanian vaccinated populations was reported that the majority of vaccinated cases of both nations were located at and below 50% of CT score severity of COVID-19 without difference (p=0.055), this could be due to efficacy of vaccination. However, when comparing non-vaccinated patients from both nations, we revealed that most of the cases lie at mid-score and above with no significant difference (p=0.639). In Szabo et al, the mean score was moderate (14.6) while in the study of Francone et al, the mean score was 18 which was associated with a high mortality rate [39, 42].

The optimal threshold score to identify severe COVID-19 was 19.5 [47]. In our study, the median score for vaccinated Iraqi cases was 17 while it was 19 for unvaccinated cases. In addition, it was 15 for Jordanian vaccinated cases and 17 for unvaccinated cases. This is similar to other studies [42, 47].

Finally, CT score positively correlated with age, WBC and platelet counts, CRP, PCT, LDH, D-dimer, ferritin, IL-6, urea, and the A-DROP score, while negatively correlated with total lymphocyte count, PaO2 and SaO2 [39].

Conclusion.

CT scan score may be suitable to assess COVID-19 severity and outcome. Mean old age, females and vaccine types could be predictors of COVID pneumonia. The most common CT scan finding was GGO. CT score threshold in vaccinated cases is lower than in non-vaccinated cases. The mortality and crude death rate among Iraqi vaccinated cases were lower than non-vaccinated people. In Jordanian vaccinated cases, the death rates are lower than non-vaccinated peoples. Female gender and unvaccinated groups are the most predictor factors to poor outcomes of disease. These data can help physicians guide management strategies for COVID-19.

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