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ORIGINAL ARTICLE

Visual scoring of chest CT at hospital admission predicts hospitalization time and intensive care admission in Covid-19

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ABSTRACT

Background: Chest CT is prognostic in Covid-19 but there is a lack of consensus on how to report the CT findings. A chest CT scoring system, ÖCoS, was implemented in clinical routine on 1 April 2020, in Örebro Region, Sweden. The ÖCoS-severity score measures the extent of lung involvement. The objective of the study was to evaluate the ÖCoS scores as predictors of the clinical course of Covid-19.

Methods: Population based study including data from all hospitalized patients with Covid-19 in Örebro Region during March to July 2020. We evaluated the correlations between CT scores at the time of admission to hospital and intensive care in relation to hospital and intensive care length of stay (LoS), intensive care admission and death. C-reactive protein and lymphocyte count were included as covariates in multivariate regression analyses.

Results: In 381 included patients, the ÖCoS-severity score at admission closely correlated to hospital length of stay, and intensive care admission or death. At admission to intensive care, the ÖCoS-severity score correlated with intensive care length of stay. The ÖCoS-severity score was superior to basic inflammatory biomarkers in predicting clinical outcomes.

Conclusion: Chest CT visual scoring at admission to hospital predicted the clinical course of Covid-19 pneumonia.

KEYWORDS
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Supplemental data for this article can be accessed here.

Introduction

The novel coronavirus disease (Covid-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is a global pandemic and a threat to human health. Up to 12 February 2021, more than two million people have died from Covid-19 in over 190 countries [1]. Although most Covid-19 patients present with mild illness, a minority of patients have severe disease characterized by pneumonia, respiratory failure, and acute respiratory distress syndrome (ARDS) [2]. The strongest independent risk factor for a severe outcome is high age [3]. Other important risk factors include male sex, cardiovascular disease, and diabetes with complications [3,4]. In certain populations, up to 30% of infected patients may require hospitalization and qualified medical support [5]. Outbreaks of Covid-19 are causing a considerable strain on the health care system with a shortage of hospital and intensive care units (ICU) beds [6]. To manage the potentially critical burden on the health care system during outbreaks and to triage individual patients, there is a need for robust prognostic models to predict the course of Covid-19.

Previous research has demonstrated a prognostic role of the extent and character of lung involvement on chest computed tomography (CT) in Covid-19 [7–9]. These studies have applied a wide range of methods to measure Covid-19 lung involvement and consequently, there is no consensus in the literature on how to assess and stage CT features of Covid-19. In addition, published predictive models have generally been developed using retrospectively interpreted CT images by expert thoracic radiologists in contrast to a clinical routine where chest CTs typically are read by general radiologists.

In response to an increased demand for chest CTs in Covid-19, a concise scoring system of lung involvement in Covid-19, the Örebro Covid-19 Scale (ÖCoS) was implemented in a clinical routine on 1 April 2020, at the Department of Radiology, Örebro Region, Sweden. The intention was to provide a standardized assessment of Covid-19 pneumonia. Both the extent of lung involvement, ÖCoS-severity score, and the character of involvement, ÖCoS-temporal stage, are assessed on the scale.

The current study is a population-based evaluation of clinically provided ÖCoS chest CT scores, including all patients hospitalized with Covid-19 in the Örebro Region during the first five months, March–July 2020, in the first outbreak wave of Covid-19 in Sweden. The primary aim was to evaluate chest CT at hospital admission as a predictor of hospital length of stay (LoS), admission to ICU and mortality. The secondary aim was to evaluate if chest CT at ICU admission correlated to ICU LoS.

Material and methods

Ethics

The Swedish Ethical Review Authority approved the study protocol and waived the requirement for informed consent for this retrospective study, reference number 2020-02515.

Study population

The study included all patients $\geq$18 years admitted to hospital due to laboratory-confirmed Covid-19 in three hospitals, one university hospital and two associated hospitals, in Örebro Region, Sweden. Covid-19 patients were identified by the ICD-codes corresponding to either a primary laboratory-confirmed diagnosis of Covid-19, or a primary diagnosis of Covid-19 based on a typical clinical presentation in combination with a positive antibody test for Covid-19, or a laboratory-confirmed secondary diagnosis of Covid-19 with a non-etiological pulmonary diagnosis as a primary diagnosis.

Management guidelines during the study period

During the study period, patients were recommended to be hospitalized if one or more of the following criteria were met; respiratory rate $>$ 24/minute after repeated measurements, oxygen saturation $SaO_2 < 93\%$ on room air, acute organ dysfunction, or general deterioration.

Patients with $SaO_2 < 93\%$ who did not reach saturation goals with 1 L oxygen/min were treated with high flow nasal oxygen in general wards up to a limit of a fraction of inspired oxygen (FiO_2) of 50% and airflow 40 L/min. Patients with multiple organ failure or lung dysfunction requiring more than 50% FiO_2 or airflow settings above 40 L/min were usually transferred to the ICU unless end-of-life decisions had been made.

Data source

Data regarding age, sex, hospitalization times, hospitalization routes, ICU admission, death during and after hospitalization, laboratory tests for Covid-19, C-reactive protein (CRP), lymphocyte count and radiology reports were extracted from the hospital information systems of the Örebro Region. Data from 1 March to 31 August 2020 was extracted, but only patients admitted to the

hospital before July 4 were included to enable at least 60 days of observation time. Patients admitted from hospitals outside the Örebro Region were excluded. Figure 1 describes the inclusion process in detail.

Chest CT

Visual scoring – Örebro Covid-19 Scale (ÖCoS)

The structured ÖCoS chest CT report was introduced on 1 April 2020. The scale consists of the disease severity score (ÖCoS-severity score) and temporal stage (ÖCoS-temporal stage) on discrete scales (Figure 2). The ÖCoS-severity score is a visual assessment of the extent of lung involvement on a six-point scale (0%, <10%, 10–25%, 25–50%, 50–75%, >75%) whereas the ÖCoS-temporal score is a five-point ordinal scale assessing the parenchymal characteristics based on the transition from normal parenchyma, via ground-glass opacities (GGO) to consolidations as described in early reports of Covid-19 evolution [10]. Radiologists were instructed to provide only one selection for the temporal stage and one selection for severity score for each examination. Scores were provided similarly

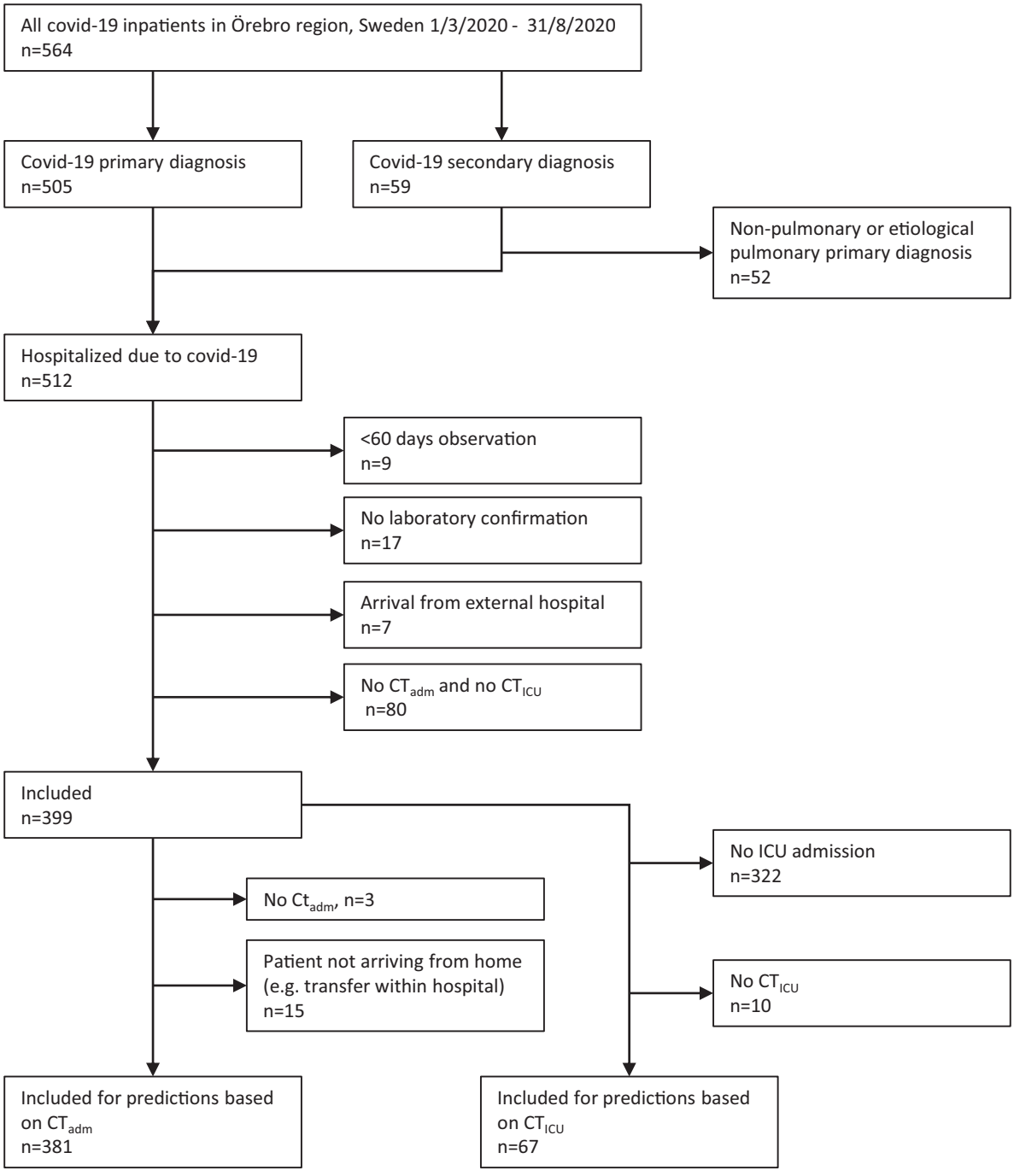

Figure 1. Inclusion and exclusion flowchart. ICU: intensive care unit; CT_{adm}: CT at hospital admission; CT_{ICU}: CT at ICU admission.

regardless of whether Covid-19 was confirmed or not at the time of reading. Figure 3 gives examples of ÖCoS scores.

The ÖCoS scores were extracted from the clinical radiology reports. Approximately 30 different radiologists and residents provided scores that were extracted for the study. In cases where no ÖCoS scores were provided, mostly because of night-time overseas teleradiological reading and CT performed before April 1, a retrospective ÖCoS scoring for the study was performed by a radiology resident (MW) blinded to all clinical information.

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Örebro Covid-19 Scale (ÖCoS)
I. Temporal stage (parenchymal pattern)
N. No lung involvement
A. Only ground-glass opacities (GGO)
B. Predominantly GGO with some consolidations
C. Approximately equal amounts of GGO and consolidations
D. Predominantly or exclusively consolidations

II. Severity score (extent)
0. No lung involvement
1. <10%
2. 10-25%
3. 25-50%
4. 50-75%
5. >75%
==========

Figure 2. The Örebro Covid-19 Scale. GGO: ground glass opacities. Crazy-paving pattern was assessed as GGO and organizing pneumonia pattern as consolidations. Only one selection for temporal stage and one selection for severity score was allowed. Stage N was always combined with severity 0 (N/0), and stages A–D were always combined with severity 1–5.

CT timing

The CT at hospital admission (CT_{adm}) was defined as the chest CT closest in time to hospital admission, with no longer than two days difference. The CT at ICU transfer (CT_{ICU}) was defined as the chest CT closest in time to ICU transfer, with no longer than two days difference.

Nucleic acid amplification and antibody tests

For detection of SARS-CoV-2 RNA, nasopharyngeal swab specimens were analyzed by different methods during the study period. The vast majority of samples were analyzed by an in-house real-time reverse-transcription polymerase chain reaction (RT-PCR) targeting the E gene (with an RdRp gene assay as confirmation) adapted from the protocol recommended by WHO, or the RdRp gene assay alone. For antibody testing, the Diasorin (Saluggia, Italy) Liaison XL test for SARS-CoV-2 IgG was used, in combination with Euroimmun (Lübeck, Germany) SARS-

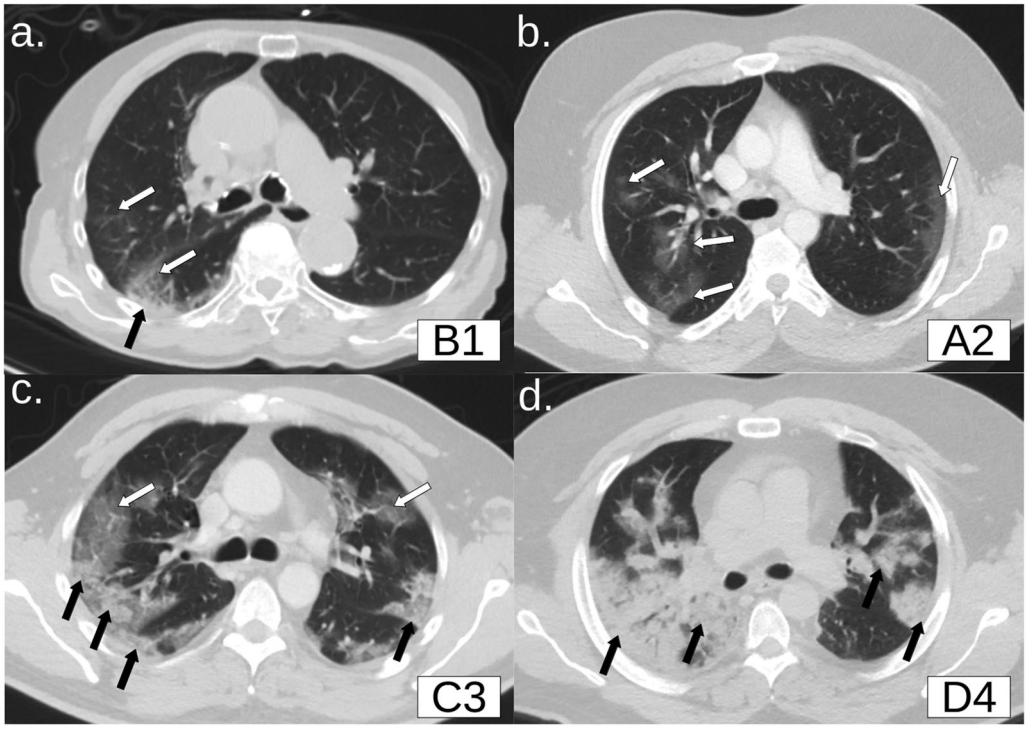

Figure 3. Lung window chest CT axial images at the level of carina demonstrating examples of Örebro Covid-19 Scale (ÖCoS) temporal stage and severity score. White arrows – ground-glass opacities (GGO). Black arrows – consolidations. (a) ÖCoS-temporal/severity B/1 (predominantly GGO, <10% lung involvement). (b) ÖCoS A/2 (Only GGO, 10–25% lung involvement). (c) ÖCoS C/3 (Approximately equal GGO and consolidations, 25–50%). (d) ÖCoS D/4 (Predominantly consolidations, 50–75%).

Table 1. Patient demographics, outcomes and ÖCoS scores at hospital and intensive care unit admission.

	Total cohort Count (%)	ICU cohort Count (%)
Cohort size	381	67
Sex, female	184 (48.3%)	23 (34.3%)
Age, years[a]	60 (50–74)	58 (50–68)
>70 years	120 (31.5%)	10 (14.9%)
Hospital free days within 60 days[a]	51 (39–56)	26 (0–40)
ICU free days within 60 days[a]	60 (60–60)	43 (20–49)
Admitted to ICU	74 (19.4%)	..
Death	46 (12.1%)	10 (14.9%)
ÖCoS-temporal stage	At hospital admission	At ICU admission
Typ N (No lung involvement)	25 (6.6%)	0 (0.0%)
Typ A (Only GGO)	84 (22.0%)	7 (10.4%)
Typ B (GGO with some consolidations)	125 (32.8%)	21 (31.3%)
Typ C (equal amounts of GGO and consolidations)	56 (14.7%)	17 (25.4%)
Typ D (Predominantly or exclusively consolidations)	91 (23.9%)	22 (32.8%)
ÖCoS-severity score	at hospital admission	at ICU admission
0. No lung involvement	25 (6.6%)	0 (0.0%)
1. <10%	86 (22.6%)	2 (3.0%)
2. 10–25%	135 (35.4%)	6 (9.0%)
3. 25–50%	95 (24.9%)	28 (41.8%)
4. 50–75%	33 (8.7%)	25 (37.3%)
5. >75%	7 (1.8%)	6 (9.0%)
C-reactive protein (mg/L)[a,b]	72 (36–132)	124 (65–193)
Lymphocyte count ($\times 10^9$/L)[a,b]	1.0 (0.7–1.3)	1.0 (0.7–1.2)

Note. [a]Median (interquartile range). [b]At hospital admission.

CoV-2 IgG ELISA for confirmation in weakly positive samples to increase specificity.

Inflammatory biomarkers

The inflammatory biomarkers CRP and lymphocyte count in blood samples drawn closest in time to hospital admission, with no longer than two days difference were included as covariates in regression analyses.

Outcome measures

Hospital LoS

To summarise the effect of Covid-19 on hospitalization time in the presence of the competing event of death, we used the composite measure hospital-free days 60 days post-admission (HFD_{60}). For each patient, the total number of HFD_{60}, including readmissions, during the 60 days following the first admission to the hospital with Covid-19 was computed. The hospital LoS was defined as 60-HFD_{60}. This outcome equals the hospitalization time within 60 days in non-deceased patients whereas deceased patients and patients with a hospitalization time over 60 days will have a hospital LoS of 60.

Combined ICU admission and mortality rate

The combined risk for ICU admission or death within 60 days was used as an outcome measure in multivariate logistic regression.

Time to ICU admission

The intervals in days between CT_{adm} and ICU admission were derived for all patients admitted to an ICU.

ICU LoS

For patients admitted to an ICU, the 60-day ICU free time (IFD_{60}) following the day of ICU transfer was computed. The ICU LoS used in the analysis was 60-IFD_{60}, which corresponds to the total ICU-time within 60 days in non-deceased patients.

Statistics

Matlab R2020a (The MathWorks Inc., Natick, MA) was used for statistics.

Multivariate linear regression with 60-HFD_{60} as a dependent variable was performed to identify the predictors for LoS. Age, CRP and lymphocyte count were treated as continuous variables whereas ÖCoS temporal stage, ÖCoS severity score and sex were treated as categorical variables. A reduced model was developed, where the temporal stages A, B and C were grouped, forming the temporal stages: N (No lung involvement), ABC (GGO extent greater than or equal consolidation extent), and D (Predominantly consolidations), (Figure 2). No blood sample biomarkers were included in the reduced model. Only linear terms with no interactions were included in the models. Twenty-fold cross-validation was performed to assess overfitting on the reduced linear regression model with LoS as the dependent variable.

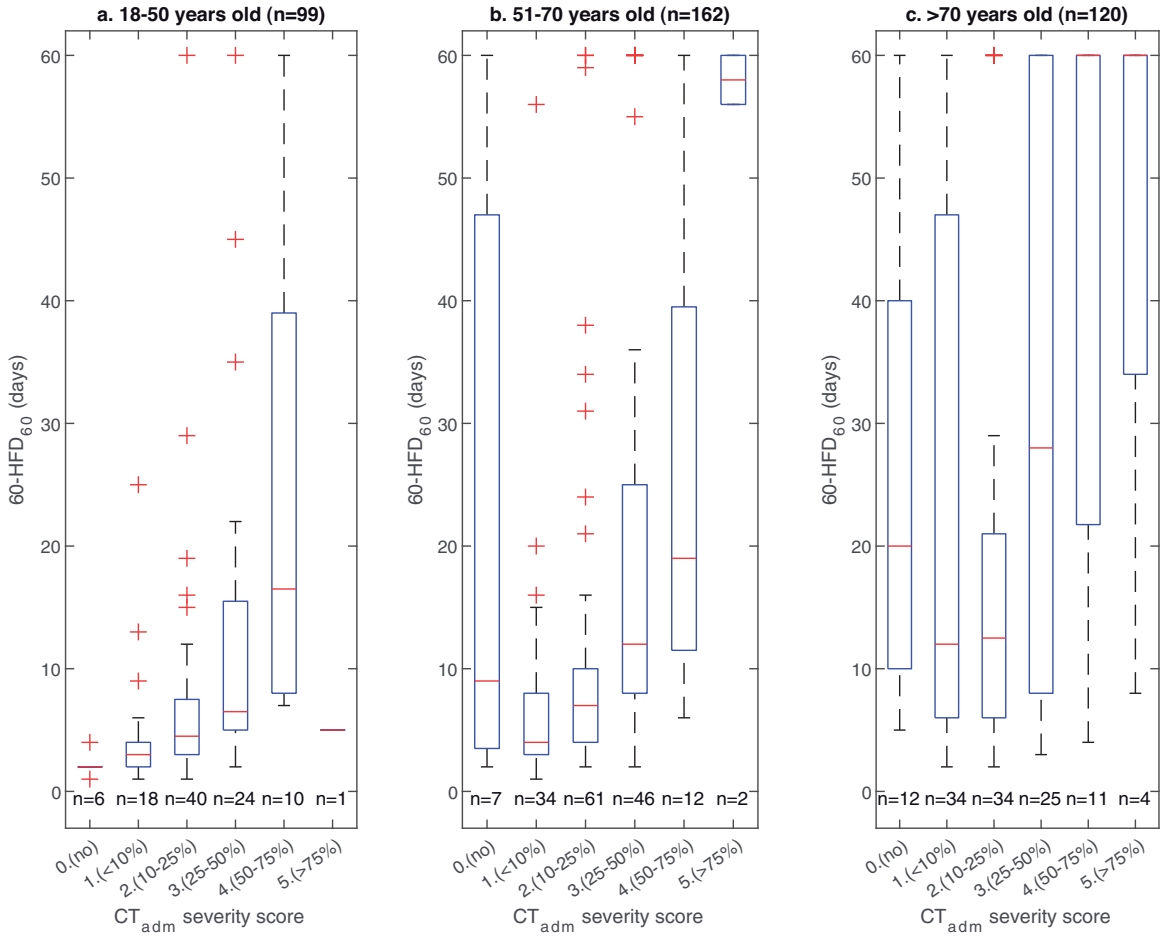

Figure 4. Box plot showing hospital length of stay, defined as 60-HFD_{60}, in relation to ÖCoS severity score on CT at hospital admission for (a) 18–50 years old, (b) 51–70 years old, and (c) >70 years old. HFD_{60}: 60-day hospital free living days.

Multivariate logistic regression with combined outcome ICU admission and death was performed with categorical variables as in the full linear regression model described above, patient age dichotomized as over or under 70 years, CRP dichotomized at 75 mg/L and lymphocyte count at 1.0×10^9/L.

For the analysis of time to ICU admission, the Spearman correlation coefficient was computed for CT_{adm} ÖCoS-severity score, CT_{adm} ÖCoS-temporal stage and age, and Wilcoxon rank-sum test was used to assess the dependency of patient sex.

For the analysis of ICU LoS, the Spearman correlation coefficient was used to assess the dependency of CT_{ICU} ÖCoS-severity score, CT_{ICU} ÖCoS-temporal stage and age, and Wilcoxon rank-sum test was used to assess the dependency of patient sex.

Results

Patient characteristics

Inclusion and exclusion of study patients is described in Figure 1. During the study period, 512 patients were hospitalized due to Covid-19. Of the 399 patients included in the study, 77 (19%) were admitted to an ICU. Among patients treated in the ICU there was a higher proportion of men and patients <70 years of age, compared to the total cohort (Table 1). In 393 of 399 included patients, SARS-CoV-2 RNA was confirmed by RT-PCR and the additional six patients were included based on a typical clinical presentation supported by a positive Covid-19 antibody test.

Clinically provided ÖCoS scores were available in 309 out of 381 CT_{adm}, and in 53 out of 67 CT_{ICU}. CRP and lymphocyte count were available in 380 and 375 patients, respectively. At hospital admission, the median (interquartile range) CRP was 20 (3–85) mg/L, 37 (21–67) mg/L, 67 (38–110) mg/L, 112 (65–183) mg/L, 142 (96–207) mg/L, and 215 (120–285) mg/L for patients with ÖCoS 0, 1, 2, 3, 4 and 5, respectively. The median (interquartile range) lymphocyte count was 1.2 (0.8–1.8) $\times 10^9$/L, 1.0 (0.7–1.6) $\times 10^9$/L, 1.0 (0.8–1.3) $\times 10^9$/L, 0.9 (0.7–1.1) $\times 10^9$/L, 0.9 (0.7–1.0) $\times 10^9$/L, and 0.8 (0.7–1.5) $\times 10^9$/L for patients with ÖCoS 0, 1, 2, 3, 4 and 5, respectively.

Table 2. Multivariate linear regression with hospital length of stay, defined as 60-HFD60 as dependent variable ($n = 381$).

	Multivariate model Coefficient (days)	*p*-Value	Reduced model Coefficient (days)	*p*-Value
Constant term	−4.9	.34	−7.3	.13
Age	0.38	<.001	0.40	<.001
Sex (M vs. F)	3.3	.06	4.5	.013
CT temporal stage		.11		.048
N. No lung involvement	Reference		Reference	
A. GGO exclusively	−6.0	.14		
B. GGO > consolidation	−8.5	.04	−6.6 (A/B/C)	.092 (A/B/C)
C. GGO ≈ consolidation	−7.5	.11		
D. predominantly or exclusively consolidations	−11.0	.012	−10.1	.018
CT severity score		<.001		<.001
0–1. <10%	Reference		Reference	
2. 10–25%	0.7	.78	1.2	.62
3. 25–50%	8.9	.002	10.5	<.001
4. 50–75%	17.9	<.001	20.0	<.001
5. >75%	27.0	<.001	29.7	<.001
C-reactive protein (mg/L)	0.027	.037		
Lymphocyte count ($\times 10^9$ /L)	−1.5	.11		

In the reduced model, temporal stage A: only ground glass opacities (GGO), B: GGO with some consolidations, and C: approximately equal amounts of GGO and consolidations were grouped.
Note. GGO: ground-glass opacities; HFD_{60}: 60-day hospital free days.

During the inclusion period, hospitalized Covid-19 patients were treated with a standard of care in line with international recommendations at the time [11,12], including oxygen support and low-molecular-weight heparins.

Hospital LoS

The hospital LoS, in relation to CT_{adm} ÖCoS-severity scores are shown for different age groups in Figure 4. In patients ≤70 years old there was a close correlation between the ÖCoS severity score and the LoS, while the ÖCoS-severity score was less clearly correlated to the LoS in older patients.

The multivariate regression analysis identified patient age, ÖCoS-severity score and CRP as significant predictors for LoS (Table 2). Since temporal stages A, B and C demonstrated similar coefficients in the multivariate analysis, a reduced model was developed with temporal stages A, B and C grouped. In the reduced model, the temporal stage was a significant predictor, and there was a consistent reduction in hospital LoS for temporal stage D (predominantly consolidations) compared to earlier stages A–C (demonstrating more GGO) and the first stage N (no lung involvement), Table 2.

The root mean square errors (RMSE) of the full model and the reduced model were similar, 16.8 and 17.2 days, respectively, indicating little loss of information in the reduction of predictors. Twenty-fold cross-validation of the reduced model linear regression showed a comparable RMSE, 17.6 days, indicating only minor overfitting in the model.

The coefficients in the linear regression provide an interpretation of the impact of each variable in terms of LoS days: the LoS increased by four days per ten years age difference and by three days in males compared to females. A higher ÖCoS severity score was associated with longer LoS: Compared to ÖCoS 0–1 (<10% extent), LoS in patients with ÖCoS 2 (10–25%) at admission increased one day, ÖCoS 3 (25–50%) nine days, ÖCoS 4 (50–75%) 18 days, and ÖCoS 5 (>75%) 27 days. CRP at hospital admission had a lower impact than ÖCoS scores on LoS. When adjusted for ÖCoS CT score and age, the LoS increased less than three days per each CRP increase in steps of 100 mg/L.

A more advanced ÖCoS-temporal stage, suggesting a later phase of Covid-19 pneumonia at hospital admission, was associated with a shorter LoS. Compared to ÖCoS N (no lung involvement), LoS in patients with ÖCoS A–C at admission (GGO extent up to equal consolidation extent) decreased seven days and ÖCoS D (predominantly consolidations) decreased ten days according to the reduced model.

ICU admission and mortality rate

The 60-day mortality rate was 12.1% in the total cohort and 14.9% in ICU-cohort as shown in Table 1. Figure 5 shows the combined ICU admission and mortality rate in relation to ÖCoS-severity score at hospital admission. In the multivariate logistic regression analysis, patient age was dichotomized as over or under 70 years. The analysis identified the ÖCoS-severity score at hospital admission ($p < .001$), patient sex ($p = .018$) and age ($p = .007$) as significant predictors for the combined outcome of ICU admission and mortality (Table 3). Neither

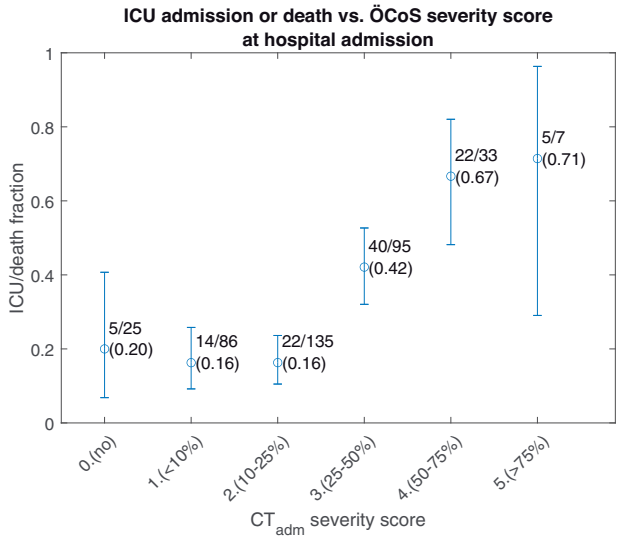

Figure 5. Combined ICU admission and 60-day mortality rate in relation to ÖCoS severity score on CT at hospital admission. Whiskers show 95% confidence interval for the proportion. ICU: intensive care unit; ÖCoS: Örebro Covid-19 Scale.

Table 3. Logistic regression with combined outcome Intensive Care Unit (ICU) admission and death ($n = 381$).

	Multivariate model Odds Ratio (95% C.I)	*p*-Value
Age > 70 years old	2.1 (1.2–3.7)	.007
Sex (M vs. F)	1.9 (1.1–3.2)	.02
CT visual type		
N. No lung involvement	Reference	
A. GGO exclusively	0.9 (0.3–3.2)	.92
B. GGO > consolidation	0.7 (0.2–2.4)	.55
C. GGO ≈ consolidation	0.7 (0.2–2.8)	.62
D. consolidation exclusively or predominantly	0.6 (0.2–2.2)	.44
CT visual extent		
0–1. <10%	Reference	
2. 10–25%	0.9 (0.4–2.1)	.88
3. 25–50%	3.9 (1.7–8.9)	.001
4. 50–75%	10.7 (3.8–30)	<.001
5. >75%	10.4 (1.7–63)	.011
C-reactive protein >75 mg/L	1.6 (0.9–2.7)	.11
Lymphocyte count < 1.0×10^9/L	0.9 (0.5–1.5)	.62

Note. GGO: ground-glass opacities.

CRP nor lymphocyte counts were statistically significant predictors for ICU-admission or death (Table 3).

Time to ICU transfer

The interval between the CT_{adm} and ICU transfer was inversely related to the ÖCoS-severity score at admission ($p = .002$), and ÖCoS-temporal stage at admission ($p = .051$), but was not significantly associated with age ($p = .15$). There was no significant difference between male and female patients ($p = .39$). The interval between CT_{adm} and ICU admission was longer for lower ÖCoS-severity scores and earlier ÖCoS-temporal stages (Figure 6).

ICU LoS

The relationships between ÖCoS scores at the time of ICU transfer (CT_{ICU}) and ICU outcomes are shown in Figure 7. The ICU LoS was positively correlated to CT_{ICU} ÖCoS-severity score ($p < .001$), and inversely correlated to CT_{ICU} ÖCoS-temporal stage ($p = .044$). The ICU LoS was correlated to patient age ($p < .001$), but not to patient sex ($p = .33$).

Discussion

Covid-19 is an ongoing pandemic causing hospital crowding and shortage of ICU beds during outbreaks. The disease has a variable prognosis and established validated scores such as CURB-65 have low overall performance in Covid-19 [13,14]. Instead, we demonstrate that clinically provided chest CT visual scores at hospital admission robustly predict the clinical course of Covid-19 and that chest CT at ICU admission can predict ICU time, especially in patients up to 70 years old.

The two aspects of the ÖCoS visual score (the temporal development of the CT pattern from GGO to consolidations, and severity of lung involvement) were closely correlated to patient outcomes. In particular, the ÖCoS-severity score, a visual estimation of the extent of lung involvement at hospital admission, was a strong independent predictor of uneventful outcome in terms of death or ICU admission, and hospital LoS. Although CRP was a significant predictor for hospital LoS, it was less discriminatory than the ÖCoS severity score (Table 2). Moreover, when adjusted for ÖCoS score and age, neither CRP nor lymphocyte counts were significantly associated with ICU admission or death in a multivariate logistic regression model, which supports the important prognostic role of the ÖCoS scores (Table 3).

The weaker association of the ÖCoS scores and patient outcomes in elderly patients, >70 years, maybe due to frequent co-morbidities creating a more complex relationship. A potential bias would be that patients with end-of-life decisions, which are more common in elderly patients, were not transferred to ICU in case of deterioration. However, because of the outcomes used in the study the risk of such bias is limited. The outcome of hospital-free days also accounts for the competing event of death and ICU admission was analyzed as a combined outcome with death. The relatively small difference in mortality in the general cohort compared with the ICU cohort is most likely due to a selection of younger patients for ICU care.

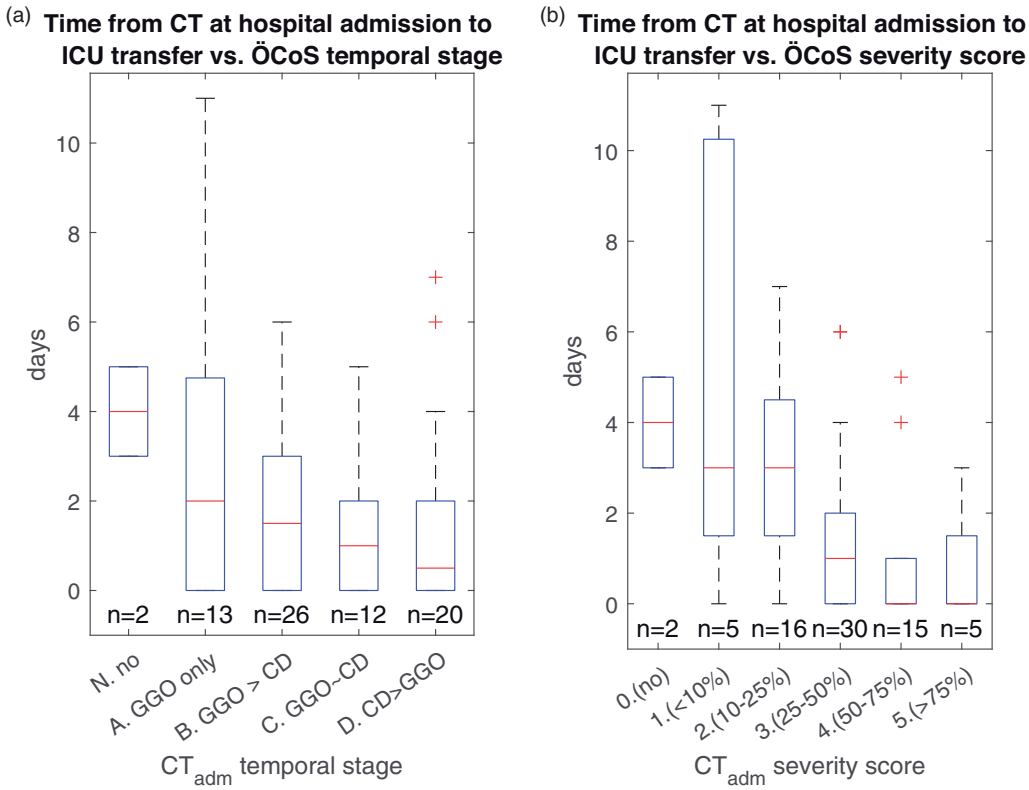

Figure 6. Time between first CT at hospital admission and ICU transfer according to (a) ÖCoS-temporal stage and (b) ÖCoS-severity score. ICU: intensive care unit; ÖCoS: Örebro Covid-19 Scale; GGO: ground-glass opacities; CD: consolidations.

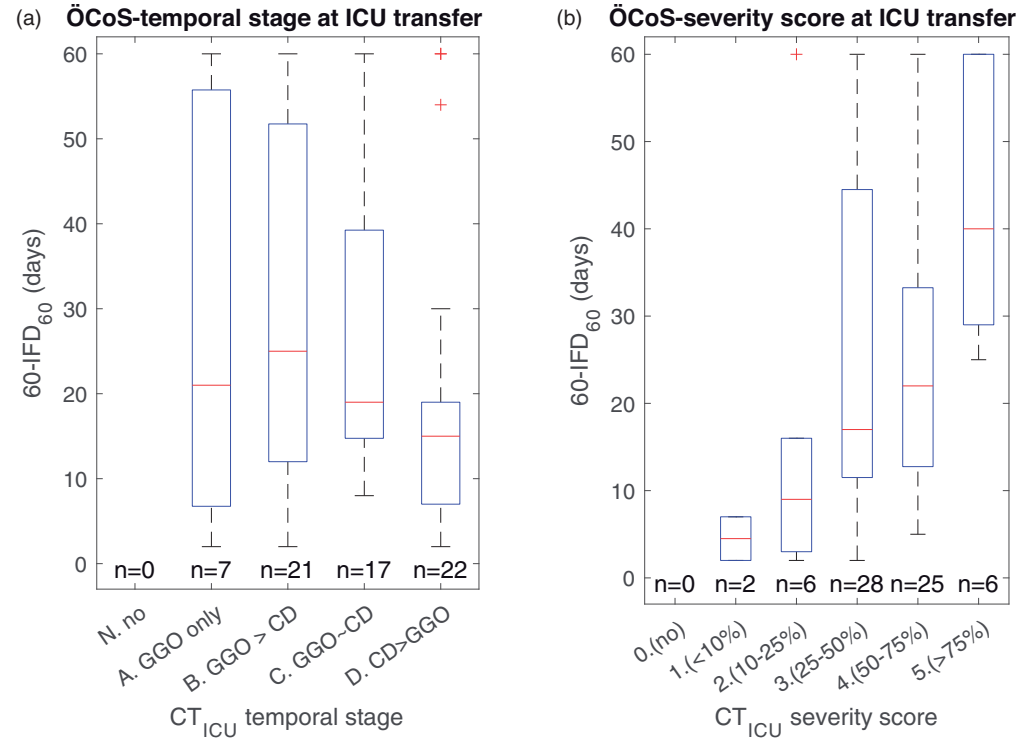

Figure 7. ICU length of stay, defined as 60-IFD_{60}, in relation to (a) ÖCoS -temporal stage, and (b) ÖCoS-severity score in CT at ICU transfer. ICU: intensive care unit; IFD_{60}: 60 day ICU free days; ÖCoS: Örebro Covid-19 Scale; GGO: ground-glass opacities; CD: consolidations.

Although different chest CT findings have been described in Covid-19, the typical features are GGO and consolidations [15]. Three findings in the current study highlight that the transition from GGO to consolidation on the ÖCoS-temporal stage reflects the clinical course in the acute phase of Covid-19 and often coincides with a deterioration of respiratory symptoms: (1) The inverse relationship of ÖCoS-temporal stage and time to ICU transfer (Figure 6), (2) the inverse relationship of ÖCoS-temporal stage at CT_{ICU} and ICU LoS (Figure 7), and (3) the shorter hospital LoS days in late ÖCoS-temporal stages at admission to hospital (Table 2).

To put the current study in context, we performed a systematic literature search (Supplementary material). In summary, we found several reports on protocols of visual quantitative analysis of CT evaluated lung involvement demonstrating a correlation to the clinical severity of Covid-19 [9,16]. In addition, several semi-automatized [8,13,17] and computerized [7,18,19] quantitative measures of Covid-19 lung involvement on CT have been associated with outcomes related to a severe course of Covid-19. However, to the best of our knowledge, up to date only one smaller study, published as a letter to the editor, reported real-life data on the predictive role of CT visual scoring in clinical routine [20].

In this study, the predictive role of chest CT could be reproduced in a non-selected population-based context with CT evaluations made by several reviewers as part of the clinical routine. Since almost 80% of the study cohort underwent chest CT on admission there was probably only a limited degree of selection of patients referred for CT. We used a concise visual scoring system as a predictive model for the outcome of hospitalized Covid-19 patients. A strength is that the model apart from patient age and sex, relied solely on CT findings, excluding clinical and laboratory data. The results indicate that triage with chest CT on admittance to the hospital would be a valuable tool for Covid-19 patients, provided that a consistent scoring system is applied. The simplicity of the chest CT ÖCoS scoring enables straightforward implementation in clinical practice, supported by its rapid acceptance among reading radiologists and referring clinicians in the Örebro Region, Sweden. Moreover, a strength of this study is that we could, in contrast to other studies, provide outcome-data up to 60 days post-admission including mortality after hospital discharge.

The study has several limitations. Consistent with the inclusion criteria, the results only apply to hospitalized patients. Additionally, the results are based on data during the early outbreak period of Covid-19 and at this time steroid treatment was not generally recommended in severe Covid-19. Further limitations are the lack of clinical data regarding oxygen support as well as more comprehensive laboratory reports. The use of scores provided by multiple radiologists is a limitation, but also a strength, in the study. Visual scoring is subjective and prone to interobserver variation, which reduces the precision of the provided scores. On the other hand, the scores used in the study are a reasonable estimate of the precision in a clinical scenario. Since the ÖCoS scores were provided in clinical routine, the reviewers were not formally blinded, but the main study outcomes of HFD_{60} and ICU admittance were naturally unknown to reviewers at the time of chest CT evaluation. Furthermore, we only included laboratory-confirmed cases of Covid-19, and consequently, some Covid-19 cases were likely excluded from the analysis [21].

In conclusion, concise visual scoring of chest CT at hospital admission and at ICU transfer independently predicted the clinical outcome of Covid-19, especially in patients <70 years. In situations where adjuvant treatments and hospital beds are limited, we believe that scoring of chest CT is informative and a valuable tool for clinical decision making.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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