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MAJOR ARTICLE

Matched Cohort Study of Convalescent COVID-19 Plasma Treatment in Severely or Life Threateningly Ill COVID-19 Patients

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Background. The utility of convalescent coronavirus disease 2019 (COVID-19) plasma (CCP) in the current pandemic is not well defined. We sought to evaluate the safety and efficacy of CCP in severely or life threateningly ill COVID-19 patients when matched with a contemporaneous cohort.

Methods. Patients with severe or life-threatening COVID-19 were treated with CCP according to Food and Drug Administration criteria, prioritization by an interdisciplinary team, and based on CCP availability. Individual-level matched controls (1:1) were identified from patients admitted during the prior month when no CCP was available. The safety outcome was freedom from adverse transfusion reaction, and the efficacy outcome was a composite of death or worsening O_2 support. Demographic, clinical, and laboratory data were analyzed by univariate and multivariable regression analyses accounting for matched design.

Results. Study patients (n = 94, 47 matched pairs) were 62% male with a mean age of 58, and 98% (90/94) were minorities (53% Hispanic, 45% Black, non-Hispanic) in our inner-city population. Seven-day composite and mortality outcomes suggested a nonsignificant benefit in CCP-treated patients (adjusted hazard ratio [aHR], 0.70; 95% CI, 0.23–2.12; P = .52; aHR, 0.23; 95% CI, 0.04–1.51; P = .13, respectively). Stratification by pretransfusion mechanical ventilation status showed no differences between groups. No serious transfusion reactions occurred.

Conclusions. In this short-term matched cohort study, transfusion with CCP was safe and showed a nonsignificant association with study outcomes. Randomized and larger trials to identify appropriate timing and dosing of CCP in COVID-19 are warranted.

Trial Registration. ClinicalTrials.gov Identifier: NCT04420988.

Keywords. convalescent plasma; COVID-19; hospitalized; matched cohort study; mortality.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the cause of coronavirus disease (COVID-19), has infected >13.7 million people around the world, with close to 600 000 deaths [1, 2]. While numerous trials are underway for prevention and treatment of COVID-19, at present there are no proven therapeutic options for patients other than remdesivir, which has demonstrated a decrease in length of hospitalizations [3, 4].

Convalescent COVID-19 plasma (CCP) is plasma that is collected from individuals who have recovered from COVID-19 and have presumed or proven antibodies to SARS-CoV-2. CCP therapy may have the potential to limit the severity of illness in patients infected with SARS-CoV-2 and may also have efficacy in preventing infection in individuals at high risk for contracting SARS-CoV-2 [5]. In the current pandemic, 2 reports from China on the use of CCP to treat patients with COVID-19 have suggested improvement [6, 7], whereas a third report on the use of CCP in an open-label multicenter randomized study did not [8]. As per ClinicalTrials.Gov, worldwide there are currently close to 200 studies recruiting COVID-19 patients to examine the effects of plasma in these patients [9]. Numerous trials have limited control groups or rely on data for controls from published randomized controlled trials [9, 10].

Our study reports on the safety and efficacy of CCP in 47 COVID-19 patients who received CCP treatment and were matched 1:1 by individual-level matching to 47 contemporaneous COVID-19 control patients who were admitted to our hospital in the month prior when CCP was not available.

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METHODS

We employed a retrospective matched cohort study design to assess short-term outcomes pertaining to the safety and efficacy of CCP treatment in severely or life threateningly ill COVID-19 patients. Our treatment patients were comprised of COVID-19 hospitalized patients who received CCP treatment under eIND approvals and expanded-access IND approvals for compassionate use [11]. CCP-treated patients were matched 1:1 using individual-level matching to contemporaneous non-CCP-treated COVID-19 patients who were admitted to our center when CCP treatment was not yet available. Clinical criteria for severe or life threatening COVID-19 were defined per Food and Drug Administration (FDA) criteria and included laboratory-confirmed COVID-19. Severe disease included 1 or more of the following: shortness of breath, respiratory frequency ≥30/min, blood oxygen saturation ≤93% on room air, partial pressure of arterial oxygen to fraction of inspired oxygen ratio <300 or lung infiltrates >50% within 24 to 48 hours. Life-threatening disease was defined as 1 or more of the following: respiratory failure, septic shock, or multiple organ dysfunction or failure [11].

SARS-CoV-2 Infection Was Confirmed by Real-time Polymerase Chain Reaction Assay

We excluded patients who had a contraindication to transfusion (severe volume overload, history of anaphylaxis to blood products); severe multi-organ failure with hemodynamic instability requiring high doses of vasopressor agents; other documented uncontrolled infection; severe disseminated intravascular coagulation (DIC) needing factor replacement, fresh frozen plasma (FFP) or cryoprecipitate; acute renal failure requiring dialysis; active intracranial bleeding; or clinically significant myocardial ischemia.

Decisions for treatment with CCP were made daily after review of COVID-19 patients by an interdisciplinary team comprised of hospitalists and clinicians from Infectious Diseases, Critical Care, and General Medicine departments. Patients were transfused according to the number of ABO-compatible (i.e. Blood groups A, B, AB, and O) plasma units available and prioritization of patients by the interdisciplinary team in each ABO group. If there was clinical equipoise between 2 or more patients for an available unit, our medical ethicist was consulted to ensure that medical ethical principles were applied to clinical decision-making. In patients where CCP therapy was thought to be futile, it was not offered. CCP was received from the New York Blood Center (NYBC) from recovered COVID-19 patients. Antibody titers were not available at the time of transfusion. Approximately 200 mL of ABO-compatible plasma was used for each transfusion. One unit of plasma was infused at baseline, and up to 2 additional units were used during the follow-up period based on plasma availability and the need of other patients at our institution.

Patient Consent Statement

Informed consents were obtained from patients or their surrogates before transfusion. The study protocol was approved by the Rutgers Institutional Review Board (IRB).

Following consent, a request was sent to the FDA for each patient for an eIND approval. Individual eINDs were used for the first 42 patients. Subsequently, an expanded-access IND was granted. Monitoring of patients during and following their infusion followed our institution's blood bank transfusion protocol.

A cohort of COVID-19 patients admitted to our institution between March 11, 2020, and April 3, 2020, before availability of CCP, were identified as contemporaneous controls and were matched to our CCP-treated patients using individual-level matching. CCP became available as of midnight of April 10, 2020. Treated and control patients were matched 1:1 by gender, race (Black non-Hispanic vs other), ethnicity (Hispanic vs non-Hispanic), age (+/- 5 years), level of oxygen (O_2) support, and duration of O_2 support at the time of initial CCP transfusion (+/- 3 days). We did not encounter more than 1 identically matched control per treatment patient; hence, there was no need to apply any random selection techniques. O_2 support at baseline was divided into 4 groups: (A) nasal cannula O_2 at 4–6 L/min; (B) high-flow nasal cannula (HFNC) O_2 (>40 L/min) or 10–15-L non-rebreather face mask (NRBFM); (C) continuous positive airway pressure (CPAP) or bi-level positive airway pressure (BiPAP); and (D) mechanical ventilation with FiO_2 >50%. Plasma patients in groups A and D were exact matches (15 and 9, respectively). Of the 23 matched pairs in groups B and C, 20 were exact matches and 2 treatment patients in group C matched to controls in group B and 1 treatment patient in group B matched to a patient in group C. Age match was within 5 years in 40 matched-pairs and 6 years in 5 matched-pairs. On 1 occasion each, an age difference of 7 and 8 years between the treatment patient and matched control was observed.

The study follow-up began with time from infusion of CCP. The exact date and time of CCP infusion were available for treated patients. For all matched controls, study enrollment start time was assigned as 12:00 noon on the day they matched their respective treatment pair's days spent on the same O_2 support pretransfusion. Duration of the same O_2 support pretransfusion was similar (+/- 3 days) in 44/47 (94%) of the matched pairs. All study patients were followed for 7 days from infusion time and were assessed for change in levels of laboratory measures, O_2 support, mortality, or discharge.

Study Patients

For this study, we reviewed the first 95 consecutive COVID-19 patients who received CCP treatment at our center between April 11, 2020, and May 18, 2020. One patient did not satisfy inclusion criteria for expanded access and was excluded from further review. Out of the remaining 94 CCP-treated patients, 47 could be successfully matched to controls

from a potential pool of 274 COVID-19 patients admitted between March 11, 2020, and April 3, 2020, 1 week before the availability of CCP at our institution. Hence, our study population comprised a total of 94 patients or 47 1:1 matched CCP treatment–control patients. Study follow-up of at least 7 days was complete for all 47 matched pairs at the time of completion of data collection.

All patients received standard-of-care treatment and oxygen support commensurate with clinical need. Treatments for COVID-19 with specific medications including hydroxychloroquine, azithromycin, doxycycline, interleukin (IL)-6 inhibitors (mostly tociluzumab), other antimicrobials, steroids, and anticoagulants were prescribed according to treating teams. None received remdesivir or monoclonal antibodies. Anti-COVID-19 treatments changed rapidly during the study period. Initial regimens comprised of hydroxychloroquine, azithromycin, and doxycycline were soon found to be ineffective, though they seemed initially promising. They were gradually replaced with IL-6 inhibitors as newer information became available.

Demographic, clinical, laboratory, and treatment information of all CCP-treated and matched control patients was retrieved from the electronic medical record. All post-transfusion laboratory measures were obtained within 24–72 hours of CCP transfusion. Changes in oxygen support were tracked daily from pretransfusion (day 0) through day 7 post-transfusion. The date and time of discharge or death of study patients were also recorded. Study follow-up was limited to 7 days. The last control patient was enrolled on April 3, 2020, providing the 7-day follow-up by April 10, 2020, when CCP became available at our institution.

Outcome Measures

Safety outcomes of CCP plasma infusion included screening for allergic reactions, transfusion-associated circulatory overload (TACO), and transfusion-associated acute lung injury (TRALI). Efficacy outcomes were a composite at 7 days of either worsening of O_2 support (2-point deterioration from before infusion or 1 point if change was to mechanical ventilation) or mortality; day 7 mortality alone; and day 7 worsening of O_2 support. A 5-level oxygen support scale was used to describe the level of oxygen support: 1, no support (or room air); 2, nasal cannula; 3a, high-flow nasal cannula (HFNC) or non-rebreather face mask (NRBFM); 3B, continuous positive airway pressure (CPAP) or bi-level positive airway pressure (BiPAP); 4, mechanical ventilation. Worsening of oxygen support was defined as 2-point deterioration of oxygen support or getting put on a mechanical ventilator. Assessment of 7-day outcomes was completed for all study patients. Seven-day composite and mortality-alone outcomes were analyzed as both binary (yes/no) and time-to-event variables. We also compared levels of inflammatory markers and other laboratory measures pre- and post-transfusion in the treatment and control groups. All laboratory measurements were analyzed as continuous variables without any transformation.

Drs. Klapholz and Pentakota had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Dr. Pentakota performed the data analyses.

Statistical Analysis

We used means and SDs to describe normally distributed variables (age and body mass index [BMI]) and medians and interquartile ranges (Q1–Q3) to describe skewed continuous variables (all laboratory measures). Counts and proportions were used to describe categorical variables. First, to assess the degree of success of our matching efforts, we used standardized differences (std. diff.) to compare our treated and control patients [12]. Cutoff levels of 0.2, 0.5, and 0.8 were a priori determined to indicate small, medium, and large differences between the 2 groups [12, 13].

Second, univariate analyses using the Wilcoxon signed-rank test were performed to compare laboratory values including inflammatory markers. Additional univariate analyses comparing binary 7-day composite and mortality-alone outcomes were performed using McNemar's test. For time-to-event analyses of 7-day composite, mortality alone, and worsening of O_2 support outcomes, we used Cox proportional-hazards regression models to allow for additional adjustment of certain confounding variables. By employing a matching design, key confounding variables, such as, age, gender, race, ethnicity, specific O_2 support, and duration of that O_2 support at the time of transfusion (days), were already accounted for. Multivariable regression models accounted for additional confounding variables by including age in years, BMI, history of hypertension, history of diabetes mellitus, and usage of IL-6 inhibitors for anti-COVID-19 treatment in the models. Data on other comorbidities and treatments were available but were not included in the regression models due to small sample size, to avoid over-fitting, and to reduce multicollinearity. Hydoxychloroquine and doxycycline/azithromycin use was common in both treatment groups, and the balance in distribution of other comorbidties across the two groups achieved through matching precluded their inclusion in regression analyses. Further, we did not include steroid and anticoagulant treatments, which represented small and medium differences between the groups with limited impact on study outcomes in unadjusted models. Cox models were fit using the "STRATA" option to take the matched design into account with the ties=BRESLOW option. Stratified analyses, limited to 7-day composite outcome, were performed among those who were and were not on a mechanical ventilator pretransfusion. All reported *P* values were 2-sided, and an alpha of .05 was used to assess statistical significance. All data analyses were performed using SAS software, version 9.4 (SAS Institute, Cary, NC, USA).

Role of the Funding Source

There was no funding source. The study design, conduct, and reporting were free of any influence/interference.

RESULTS

A total of 94 COVID-19 patients comprised of 47 CCP-treated patients matched 1:1 with 47 control patients were analyzed. The mean age (SD, range) was 57.7 (13.7, 30–86) years in the control group and 58.0 (13.0, 28–81) years in the treatment group. Males comprised 61.7% of our study population. Ninety-eight percent of our patients (92/94) were minority; 53.2% were Hispanic, and 44.7% were Black non-Hispanic in both groups (Table 1). One in 5, or 20% of study patients, were on mechanical ventilation pretransfusion.

In our inner-city minority population, there was a high burden of baseline comorbid conditions. Overall, the prevalence rates of hypertension, diabetes, and obesity were 55%, 33%, and 49%, respectively (Table 1). Renal function was preserved. Twenty-five percent of study patients had a smoking history. Over time, per our institution's protocols, IL-6 inhibitors were administered more frequently and as a result there was wider usage among patients in the treatment (62%) compared to the control (26%) group. Theses differences remained despite matching (std. diff. = 0.78). This difference was accounted for by including the IL-6 inhibitor use variable in all our multivariable regression analyses. A good balance was achieved in most of the remainder potential clinical confounders (std. diff. < 0.2), indicating a good quality match.

The average day interval from hospitalization to first CCP transfusion among the CCP recipients (SD) was 4.9 (3.2) days from admission, with a median interval of 4 days. Among the 47 CCP recipients, 28 received only 1 transfusion, and 17 and 2 received 2 and 3 transfusions, respectively.

Table 2 describes and compares the medians and interquartile ranges for several inflammatory markers and other laboratory values between the treatment and control groups before and after CCP transfusion. Pretransfusion D-dimer

Table 1. Baseline Demographic and Clinical Characteristics (n = 47 Matched Pairs)[a]

Characteristic	Control, No. (%)	Convalescent Plasma, No. (%)	Standardized Difference
Age, mean (SD), y	57.7 (13.7)	58.0 (13.0)	0.02
BMI, mean (SD), kg/m^2	33.3 (8.13)	29.9 (7.0)	–0.51
Age category, y			
<50	11 (23.4)	12 (25.5)	0.15
50–<70	30 (63.8)	27 (57.5)	
≥70	6 (12.8)	8 (17.0)	
Male sex	29 (61.7)	29 (61.7)	0
Black race	21 (44.7)	21 (44.7)	0
Hispanic ethnicity	25 (53.2)	25 (53.2)	0
Oxygen support at baseline			
Nasal cannula	15 (31.9)	15 (31.9)	0.32
NRB or HFNC	22 (46.8)	19 (40.4)	
CPAP or BIPAP	1 (2.1)	4 (8.5)	
Mechanical ventilation	9 (19.2)	9 (19.2)	
Comorbidities			
Hypertension	26 (55.3)	26 (55.3)	0.00
Diabetes mellitus	17 (36.2)	14 (29.8)	–0.14
CKD Stage ≥3	3 (6.4)	1 (2.1)	–0.21
Heart failure	3 (6.4)	1 (2.1)	–0.21
HIV	. (.)	2 (4.3)	0.30
COPD	4 (8.5)	2 (4.3)	–0.17
Current or former smoker	14 (29.8)	10 (21.3)	–0.20
Asthma	4 (8.5)	5 (10.6)	0.07
Chronic liver disease	2 (4.3)	2 (4.3)	0.00
Other treatments			
IL-6 inhibitor	12 (25.5)	29 (61.7)	0.78
Doxycycline or azithromycin	43 (91.5)	29 (61.7)	–0.75
Hydroxychloroquine	42 (89.4)	41 (87.2)	–0.07
Steroids	14 (29.8)	16 (34.0)	0.09
Anticoagulation	8 (17.0)	17 (36.2)	0.44

Abbreviations: BiPAP, bilevel positive airway pressure; BMI, body mass index; CPAP, continuous positive airway pressure; COPD, chronic obstructive pulmonary disease; CKD, chronic kidney disease; HFNC, high-flow nasal canula; IL-6, interleukin-6; NC, nasal canula; NRB, non-rebreather.

[a]Individual-level 1:1 match of convalescent plasma–treated patients to controls was performed on gender, ethnicity, race (Black Non-Hispanic vs other), age (+/- 5 years), level of O_2 support, and duration of O_2 support (+/- 3 days) at time of initial convalescent plasma transfusion.

Table 2. Comparison of Laboratory Measurements (n = 47 Matched Pairs)[a]

	Control		Convalescent Plasma		
Laboratory Measurements	Missing	Median (IQR)	Missing	Median (IQR)	*P* Value[b]
Inflammatory markers					
CRP, mg/L					
Pretransfusion	6	131 (71–212)	0	117 (46–190)	.49
Post-transfusion[c]	18	117 (60–187)	4	36 (16–206)	.61
Ferritin, ng/mL					
Pretransfusion	6	1326 (662–2000)	0	870 (458–2280)	.88
Post-transfusion	16	1542 (693–1984)	2	1215 (583–1795)	.52
LDH, IU/L					
Pretransfusion	4	483 (393–654)	0	553 (391–715)	.74
Post-transfusion	18	534 (443–641)	3	542 (405–716.5)	.45
D-dimer, ng/mL					
Pretransfusion	20	1542 (1124–3155)	0	2951 (1435–7835)	.002
Post-transfusion	16	2640 (1236–5460)	2	4480 (2279–7835)	.03
IL-6, pg/mL	32	103.3 (39.2–289)	16	112.1 (63.7–230)	.37
Other laboratory measurements					
Creatinine, mg/dL					
Pretransfusion	0	0.9 (0.7–1.5)	0	0.9 (0.7–1.2)	.10
Post-transfusion	2	0.9 (0.7–1.9)	1	0.85 (0.6–1.2)	.05
AST, IU/L					
Pretransfusion	1	46.5 (40–63)	0	58 (39–103)	.30
Post-transfusion	12	45 (30–76)	4	53 (39–95)	.29
ALT, IU/L					
Pretransfusion	2	39 (31–55)	0	44 (24–79)	.20
Post-transfusion	12	42 (22–66)	4	57 (24–110)	.09

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; CCP, convalescent COVID-19 plasma; CRP, C-reactive protein; IL-6, interleukin-6; IQR, interquartile range; LDH, lactic acid dehydrogenase.

[a]Individual-level 1:1 match of convalescent plasma–treated patients to controls was performed on gender, ethnicity, race (Black Non-Hispanic vs other), age (+/- 5 years), level of O_2 support, and duration of O_2 support (+/- 3 days) at time of initial convalescent plasma transfusion.

[b]*P* values from Wilcoxon signed rank test to account for matched design.

[c]Post-transfusion labs were drawn between 24 and 72 hours after CCP transfusion among plasma recipients; for controls, these labs were drawn within 24–72 hours of their study start time.

values were significantly elevated in the treatment group (median [IQR], 2951 [1435–7835]), compared with the controls (median [IQR], 1542 [1124–3155]; $P = .002$). Levels of D-dimer increased in both groups post-transfusion and remained significantly elevated in the treatment group compared with controls ($P = .03$). This was not seen with other inflammatory markers such as C-reactive protein, ferritin, and lactate dehydrogenase, where both pre- and post-transfusion values were not statistically significantly different across the 2 groups. IL-6 levels were slightly elevated in the treatment group (median [IQR], 112.1 [63.7–230]) but were not statistically significantly different ($P = .37$) compared with the control group (median [IQR], 103.3 [39.2–289]). All other laboratory measures such as serum creatinine and aminotransferases were not clinically or statistically significantly different between groups both pre- and post-transfusion.

One CCP-treated patient included in our analysis experienced a transient increase in temperature that resolved after the infusion was discontinued and acetaminophen was administered.

Univariate Analyses of 7-Day Binary Outcomes

Tests for both 7-day outcomes failed to show any statistically significant differences between the treatment groups. The incidence of the composite outcome for worsening of O_2 support (2-point deterioration of O_2 support or being put on a mechanical ventilator or death) as of day 7 post-transfusion was slightly less common in the treatment group (14/47, 29.8%) than the control (17/47, 36.2%) group ($P = .51$). There was 1 fewer death in the treatment group (9/47, 19.2%) compared with the control group (10/47, 21.3%).

Regression Analysis for 7-Day Time-to-Event Outcomes

Results from unadjusted and adjusted Cox proportional hazards regression models, both in the overall study population and stratified analyses by being on mechanical ventilator or not pretransfusion, are presented in Table 3. The confounding effects of the variables employed to match were already minimized or accounted for during the design phase by individual-level matching. Additionally, in our multivariable regression models, we accounted for age in years, BMI, history of hypertension and diabetes mellitus, and use of IL-6 inhibitors. Results

Table 3. Risk of 7-Day Composite Outcome[a] and Mortality Alone (n = 47 Matched Pairs)[b]

		Unadjusted		Adjusted[c]	
Outcome	Events/Patients	Hazard Ratio (95% CI)	*P* Value	Hazard Ratio (95% CI)	*P* Value
Overall study population sample (n = 47 matched pairs)[b]					
7-d composite outcome					
Convalescent plasma	14/47	0.75 (0.36–1.59)	.45	0.70 (0.23–2.12)	.52
Control	17/47	Reference		Reference	
7-d mortality					
Convalescent plasma	10/47	0.80 (0.32–2.03)	.64	0.23 (0.04–1.51)	.13
Control	9/47	Reference		Reference	
7-d worsening of O_2 support among those not on ventilator pretransfusion (n = 38 matched pairs)[b]					
Convalescent Plasma	10/38	1.13 (0.43–2.92)	.81	2.38 (0.47–12.1)	.30
Control	9/38	Reference		Reference	
Stratified analyses: on mechanical ventilator pretransfusion (n = 9 matched pairs)[b]					
7-d composite outcome					
Convalescent plasma	3/9	0.33 (0.07–1.65)	.18	0.27 (0.04–1.77)	.17
Control	6/9	Reference		Reference	
Stratified analyses: not on a mechanical ventilator pretransfusion (n = 38 matched pairs)[b]					
7-d composite outcome					
Convalescent plasma	11/38	1.00 (0.42–2.40)	1.00	0.97 (0.38–2.45)	.94
Control	11/38	Reference		Reference	

Abbreviations: BMI, body mass index; IL-6, interleukin-6.

[a]Composite outcome included either mortality or 2-point deterioration of oxygen support or getting put on a mechanical ventilator. Five-level oxygen support scale was used to describe the level of oxygen support: 1, no support (or room air); 2, nasal cannula; 3a, high-flow nasal cannula or non-rebreather face mask; 3B, continuous positive airway pressure or bi-level positive airway pressure; 4, mechanical ventilation. Worsening of oxygen support was defined as 2-point deterioration of oxygen support or getting put on a mechanical ventilator.

[b]Individual-level 1:1 match of convalescent plasma–treated patients to controls was performed on gender, ethnicity, race (Black Non-Hispanic vs other), age (+/- 5 years), level of O_2 support, and duration of O_2 support (+/- 3 days) at time of initial convalescent plasma transfusion.

[c]Adjusted for age, BMI, hypertension, diabetes mellitus, and use of IL-6 inhibitors in models including overall study population; adjusted for age, BMI, diabetes mellitus, and use of IL-6 inhibitors in models limited to O_2 support worsening; age alone was adjusted for in stratified analyses.

from multivariable regression models examining the composite and mortality-alone outcomes showed no significant difference between the treatment and control groups. In the overall population, for the 7-day composite outcome of worsening oxygen support and mortality, we observed a nonsignificant adjusted hazard ratio (aHR, 0.70; 95% CI, 0.23–2.12; $P = .52$). Likewise, there were no differences between the groups for the 7-day mortality outcome (aHR, 0.23; 95% CI, 0.04–1.51; $P = .13$). When the analyses were conducted among those not on a ventilator at baseline for worsening O_2 support, we found that the risk of worsening of O_2 support increased, however, nonsignificantly, among CCP recipients (aHR, 2.38; 95% CI, 0.47–12.1; $P = .30$). Similar to the overall analyses, stratified analyses by pretransfusion mechanical ventilator status also did not show a significant association between treatment group and 7-day composite outcome. See Table 3, Supplementary Table 1, and Supplementary Table 2 for further details on the results from the various Cox regression models.

DISCUSSION

In this nonrandomized, open-label, physician-directed, FDA-guided study of the clinical use of CCP for the treatment of severely or life threateningly ill COVID-19 patients as compared with a contemporaneous matched cohort when no CCP was available, no significant clinical benefit in either the composite for worsening oxygen support and mortality or mortality alone was identified during the 7-day follow-up. These observed results were seen despite a greater burden of patients on worse oxygen support in the CCP arm compared with the control arm. Stratified analyses by pretransfusion mechanical ventilator status also showed similar nonsignificant differences. The infusion of CCP was not associated with any identifiable serious adverse transfusion reactions.

We recognize that this report is only on 47 matched pairs with only 1 week of follow-up. This resulted from our definition of potential control patients as only those who had at least 1 week of data by April 10, 2020, when CCP became available. This design allowed for our strict adherence that data on contemporaneous matched controls be completely retrospective in nature vis-à-vis our CCP-treated patients and eliminate any perceived treatment bias or potential violation of the intent of expanded access approval (ie, no CCP was available for treatment during the period of follow-up of the control patients). Nearly 60% of study patients remained hospitalized beyond 7 days. However, a longer-term comparison between the treatment and control arms is not possible with our study design, as the majority of control patients after 7 days would increasingly cross over into the period where CCP became available.

Results from a large study of 5000 COVID-19 patients who received CCP as compassionate care suggested that

CCP administration is relatively safe, but lack of controls precluded us from assessing CCP efficacy [14]. Seven-day mortality reported in this study was close to 15%, compared with close to 20% reported in our study [14]. The patients we treated were severely or life threateningly ill with high oxygen requirements and high levels of inflammatory markers. The high inflammatory markers are consistent with cytokine storm and may signify an advanced stage of disease where neutralizing antibodies may no longer be effective [8, 15]. Bullard et al. have demonstrated that despite a positive polymerase chain reaction test result, the existence of replicating viable viruses beyond the eighth day from symptom onset is doubtful [16]. Infusion of CCP becomes futile when viable viruses cease to exist. In our study, the median interval from admission to initial CCP transfusion was 4 days; that is, for a majority of these patients, the first CCP infusion might have occurred after >8 days from symptom onset, thereby rendering CCP treatment ineffectual. Similar reasons might have played a role in the World Health Organization–sponsored Solidarity trial, wherein the recently published interim results from the trial showed all 4 antiviral treatments (remdesivir, hydroxychloroquine, lopinavir, and interferon beta-1a) to be ineffective in hospitalized COVID-19 patients [17]. Our treated and matched cohorts were from an inner-city, minority population with a high prevalence of chronic comorbidities, which may have contributed to the higher mortality seen in the study patients [18].

The limitations of our study are several. The matched cohort design cannot account for unrecognized or unmeasured confounding variables. However, our treatment group had good precision with their control matches, and controls were free of treatment bias. While positivity for antibodies to SARS-CoV-2 was documented using the NYSDOH Luminex–based assay, titers were not available and may influence outcomes [19]. Plasma contains numerous other proteins, including soluble clotting factors such as fibrinogen, factor XIII, von Willebrand factor (VWF), and vitamin K–dependent coagulation factors II, VII, IX, and X. Fibrinolytic proteins are also contained at normal physiologic concentrations [20, 21]. The effect of these other factors in our patient population who received treatment with CCP is unknown and may have contributed to observed outcomes. While concerns exist for antibody-dependent enhancement with antibody-mediated worsening of infection in immune plasma therapy, we did not observe this in our population [22].

ABO blood groups may play a role in patients' outcomes in COVID-19. Non-peer-reviewed data from China suggest that group O individuals had lower rates of infection and lower mortality compared with other ABO blood types [21, 23]. We do not have the complete ABO blood group types for our control group population (missing for 55%). However, blood type was not found to be statistically significantly associated with 7-day mortality in our treatment group, with type A at 17%, type B at 29%, and type O at 18% mortality.

Convalescent plasma infused for severe or life threateningly ill COVID-19 inner-city, minority patients appears to be safe. Comparison with a matched contemporaneous control cohort suggested improvement in the treated population for 7-day outcomes but was not statistically significant. Large multicenter randomized trials with CCP (alone or in combination with other anti-COVID-19 candidate drugs) that address timing relative to disease stage and dosing or the use of CCP as a preemptive strategy for protection against SARS-CoV-2 infection in high-risk patients appear to be warranted.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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