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The first case of COVID-19 treated with the complement C3 inhibitor AMY-101

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ABSTRACT

Acute respiratory distress syndrome (ARDS) is a devastating clinical manifestation of COVID-19 pneumonia and is mainly based on an immune-driven pathology. Mounting evidence suggests that COVID-19 is fueled by a maladaptive host inflammatory response that involves excessive activation of innate immune pathways. While a “cytokine storm” involving IL-6 and other cytokines has been documented, complement C3 activation has been implicated as an initial effector mechanism that exacerbates lung injury in preclinical models of SARS-CoV infection. C3-targeted intervention may provide broader therapeutic control of complement-mediated inflammatory damage in COVID-19 patients. Herein, we report the clinical course of a patient with severe ARDS due to COVID-19 pneumonia who was safely and successfully treated with the compstatin-based complement C3 inhibitor AMY-101.

1. Introduction

The recently declared global emergency following the outbreak of SARS-CoV-2 has raised awareness about tackling COVID-19, the disease caused by SARS-CoV-2, with more effective therapeutic means. While complement is considered a first-line defense against invading pathogens [1], including viral infections, recent evidence has strikingly suggested that complement activation can promote severe acute respiratory syndrome (SARS) coronavirus pathogenesis [2,3]. Indeed, blocking C3 activation or downstream effector generation can significantly attenuate the lung-directed proinflammatory sequelae of coronavirus (CoV) infections, including MERS-CoV or SARS-CoV, limiting the pathological changes that impose a high burden on CoV-infected patients [2,4]. Both the genetic absence of C3 and blockade of downstream complement effectors, such as C5a/C5aR1, have shown therapeutic promise by containing the detrimental proinflammatory consequences of viral spread mainly via inhibition of monocyte/neutrophil activation and immune cell infiltration into the lungs [2,4].

Acute respiratory distress syndrome (ARDS) is mainly based on an immune-driven pathology that is observed in severe cases of COVID-19 [5]. The deregulated activation of multiple innate immune pathways, including the complement system, the cytokine circuitry, and several procoagulant and thrombogenic pathways, is believed to fuel a hyper-inflammatory state that drives ARDS and may lead to multiple organ injury in COVID-19 [3,6,7].

C3 activation is positioned upstream of these proinflammatory innate immune circuits that contribute to thromboinflammation and organ damage in COVID-19 [3]. Therefore, C3 interception could be a promising approach to broadly inhibit complement activation and contain systemic, complement-mediated inflammatory reactions that may fuel tissue destructive inflammation in COVID-19 patients.

A new generation of highly selective and potent C3 inhibitors, termed compstatins Cp40/AMY-101, are clinically developed by Amyndas Pharmaceuticals for various complement-mediated
indicators [8–14]. These small-sized peptidic C3 inhibitors are pri-
mate/human-specific and display more favorable pharmacological
profiles and a greater tissue-penetrating capacity than larger biologics,
such as the complement inhibitor TP-10, previously evaluated as a
treatment option for ARDS [15]. The C3-targeted therapeutic AMY-101
is currently in Phase II clinical trials having shown good safety and
tolerability in human volunteers in a Phase I study [11] [16,17]. In light
of the recent evidence linking C3 activation to a systemic proin-
flammatory response in SARS-CoV infection, AMY-101 could form a
unique base for developing adjunctive anti-inflammatory therapies to
counteract the emerging COVID-19 outbreak [3].

Recent clinical developments further supporting the therapeutic
merit of complement inhibition as a potential anti-inflammatory
therapy in COVID-19 include the report of five cases of COVID-19 pa-
tients associated with pronounced systemic complement activation,
complement-mediated microvascular injury and coagulopathy [18],
and a recent preprint reporting complement activation in lung biopsy
and serum from COVID19 patients hospitalized during the recent SARS-
CoV-2 outbreak in China [19]. While this is only a preliminary analysis
that remains to be confirmed by larger studies, the immediate clinical
improvement resulting from anti-C5a blockade in two COVID-19 pa-
tients has prompted the further investigation of this route of comple-
ment therapeutic targeting [19]. In this regard, clinical trials aiming to
evaluate the safety and efficacy of various complement targeting ap-
proaches in COVID-19 patients are now listed in international registries
(cclinicaltrials.gov).

Given that C3 interception with campstatin-based inhibitors (such as
AMY-101) may offer broader therapeutic coverage than anti-C5 or
anti-C5a agents by blocking simultaneously generation of all down-
stream proinflammatory mediators involved in SARS-CoV-2-induced
ARDS and thrombotic microangiopathies, AMY-101 is well poised for
clinical evaluation as an anti-inflammatory agent in severe cases of
COVID-19 infection [3].

2. Case presentation

Patient #1 is a 71-year-old Caucasian male, who was admitted in
the hospital for critical limb ischemia of the right leg requiring surgery.
He had a meaningful past medical history, due to history of atrial fi-
brillation (resolved at the time of hospitalization), hypercholester-
olemia and hypertension, associated with multiple arterial complica-
tions and mild kidney failure. Indeed, the patient had coronary artery
disease requiring 5 stents, and then the recent peripheral arterial dis-
 ease treated with embolectomy by Fogarty catheter. During the hospi-
talization, on April 6th the patient was diagnosed with bilateral inter-
stitial pneumonia (see chest X-ray, Fig. 1), that was eventually
demonstrated to have been caused by SARS-CoV-2 infection. Because
of severe hypoaxia irrespective of oxygen support through standard Ven-
timask, the patient had to start non-invasive mechanical ventilation
(NIV) with Continuous Positive Air-Pressure (C-PAP) with 60% of
Fraction of Inspired Oxygen (FiO2) given in 2 h cycles every 12 h. At
this time, his arterial oxygen pressure (Pao2) and his blood oxygen
saturation (SpO2) were 65 mmHg and 93%, respectively; the patient
had increased C-reactive protein (CRP, 63 mg/L), increased lactate
de-hydrogenase (LDH, 466 UI/L), leukocytosis (16.9 g/L) and lym-
phocytopenia. Patient’s performance status (PS, using the Eastern Co-
operative Oncology Group [ECOG] scale) was 3. In consideration of the
Acute Respiratory Distress Syndrome (ARDS) due to SARS-CoV-2, the
patient was considered a candidate for experimental treatments for
Coronavirus Disease 2019 (COVID-19), including the complement C3
inhibitor AMY-101, available at the San Raffaele Hospital. AMY-101 is
available at the San Raffaele Hospital within a compassionate use
program sponsored by Amyndas Pharmaceuticals S.A, which was ap-
proved by the Institutional Review Board (IRB) of San Raffaele Hospital
on March 25th.

On April 8th, the AMY-101 compassionate use was discussed with
the patient, who expressed his willingness to be included in the pro-
gram. After having signed the IRB approved informed consent, the
patient was enrolled in the AMY-101 compassionate use program.
The patient was not treated with specific antiviral therapy, whereas anti-
bacterial prophylaxis with piperacilline/tazobactam was added 2 days
before the start of AMY-101 administration and continued for the entire
treatment period. April 10th was the day that the AMY-101 treatment
started; at baseline, the patient was in poor general clinical conditions, with
severe fatigue, severe tachypnea (> 35 respiratory acts per
minute), and persistent dry cough. Pulmonary auscultation revealed
mid-inspiratory and expiratory coarse crackles, bilateral. He was in
severe ARDS, requiring C-PAP cycles (2 h every 12 h) alternating to
oxygen support through Ventimask with 60% FiO2. His lung parameters
at baseline, with FiO2 60%, were as follows: PaO2 89 mmHg, PaCO2
36 mmHg, SpO2 96%, pH 7.5, PaO2/FiO2 148 mmHg. Blood tests were as
follows: white blood cells (WBC) 11.6 × 109/L, absolute neutrophil
count (ANC) 8.6 × 109/L, absolute lymphocyte count (ALC) 1.6 × 109/
L, CRP 94.2 mg/L, LDH 306 UI/L, C3 plasma level 1.81 g/L. Additional
lab testing demonstrated mild renal function impairment and grade I
transaminase elevation. Glasgow Coma Scale (GCS) and quick Sequential
Organ Failure Assessment (qSOFA) score were 15 and 1 (for respiratory rate > 22/min), respectively.

AMY-101 was given intravenously (IV) through a peripheral vein
infusion at dose of 5 mg/kg mg/Kg/day, given as initial loading dose
administered in 6 h; no side effects were recorded after the loading
dose. Immediately after the completion of the loading dose, 13 mainte-
nance doses were administered as 24-h continuous infusions, for a 14-
day treatment period. No infusion reactions were reported during the
whole duration of the therapy; notably, the experimental treatment did
not worsen renal and hepatic function.

After 48 h from the initiation of AMY-101 treatment, the patient
showed a dramatic improvement of all parameters that were abnormal
at baseline, resulting in the quick resolution of the broad inflammatory
response associated with COVID-19. In particular, CRP and LDH pro-
gressively normalized, while leukocytosis and lymphocytopenia im-
proved more slowly but progressively (Fig. 2). These laboratory find-
ings were associated with a significant improvement of respiratory
performance with a gradual decrease of oxygen requirement (Fig. 3).
Starting from April 18th (Day 9) a progressive weaning from oxygen
supplementation was allowed. C-PAP was initially reduced to alternate
day cycles, and then discontinued on April 20th (Day 11 of AMY 101
treatment). Similarly to the progressive and continuous improvement of
blood tests, the lung function also continued to improve: indeed, the
day after C-PAP discontinuation the patient’s oxygen requirement di-
minished, with FiO2 reducing from 40% to 31% and then 28%, without
desaturation (Fig. 3). Interestingly, lung functional improvement was not
associated with major changes by imaging: indeed, the bilateral
interstitial pneumonia was still observed by a chest X-ray performed on
April 16th (Day 7), and by a subsequent CT scan performed on April
20th (Day 11), that showed also a mild right pleural effusion.

At the end of AMY-101 treatment on April 23rd (day 14), with
Ventimask at 28% FiO2, the patient had SpO2 98%, normal respiratory
rate and normal lung auscultation, in absence of any respiratory
symptom. Blood tests were as follows (Fig. 2): WBC 8.7 × 109/L, ANC
4.0 × 109/L, L, CRP 2.9 × 109/L, CRP 23.4 mg/L, LDH 145 U/L, C3
1.74 g/L. The patient had just mild fatigue, with ECOG performance
status improved to 1, overall demonstrating a significant clinical im-
provement which is anticipated to result to the quick resolution of
COVID without any further complications. Notably, the concomitant
critical limb ischemia of both legs has not worsened (no abnormalities
reported at arterial and venous ultrasound imaging performed on April
25th), and no clinical or laboratory signs of cardiovascular complication
occurred, including thrombotic microangiopathy. At the latest follow
up on April 28th (day 19) general conditions are further improved: the
patient is afibrile, without any need of oxygen support (withdrawn on
day 18). Indeed, his SpO2 in room air is 94%, with normal respiratory
rate and no respiratory symptom; at this time the chest X-ray shows a marked improvement of pneumonia with re-expansion of the lungs, bilaterally (Fig. 1B).

3. Conclusions

Treatment with the compstatin-based C3 inhibitor AMY-101 is safe, and associated with a favorable course in a patient with COVID-19 severe pneumonia with systemic hyper inflammation. These early clinical results indicate that C3 inhibition holds potential as a novel anti-inflammatory therapy in COVID-19 and pave the way for systematic prospective trials.

Disclosure statement

J.D.L. is the founder of Amyndas Pharmaceuticals, which is developing complement inhibitors for therapeutic purposes and is the inventor of patents or patent applications that describe the use of complement inhibitors for therapeutic purposes some of which are developed by Amyndas. J.D.L. is also the inventor of the compstatin technology licensed to Apellis Pharmaceuticals (i.e., 4(1MeW)7W/POT-4/APL-1 and PEGylated derivatives such as APL-2/pegcetacoplan). A.M.R. has received research support from Alexion, Novartis, Aynlam and Rapharma, lecture fees from Alexion, Novartis, Pfizer and Apellis, served as member of advisory/investigator board for Alexion, Achillion, Apellis, Biocryst, Novartis, Roche, Samsung and Sanofi, and served as consultant for Amyndas, Novartis and Omeros. D.Y. is the Managing Director of Amyndas Pharmaceuticals which is developing complement inhibitors for therapeutic purposes. The other authors declare no competing interests.

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Fig. 1. A. Chest X-ray at enrollment. The X-ray demonstrates the bilateral infiltration of the lungs leading to the diagnosis of bilateral interstitial pneumonia. B. Chest X-ray on day 19. The X-ray demonstrates a marked improvement of pneumonia with re-expansion of the lungs, bilaterally.

Fig. 2. Biomarkers of systemic inflammation during AMY-101 treatment. Changes of biomarkers of systemic inflammation during the 14-day treatment period; WBC: white blood cells; ANC: absolute neutrophil count; ALC: absolute lymphocyte count; LDH: lactate dehydrogenase; CRP: C-reactive protein.
Fig. 3. Changes of lung function during the 14-day treatment period, displayed as need of oxygen support; Panel A: Continuous Positive Air-Pressure, measured as hours of C-PAP per 12 h; Panel B: % of Fraction of Inspired Oxygen in Ventimask.

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