Dear Editor,

The SARS-CoV-2 pandemic resulted in an unprecedented number of severe cases among pregnant women [1, 2]. To date, there have been only few reports of the specific issues that arise during the intensive care treatment of pregnant women with lung failure due to Covid-19 [3, 4]. Complex medical decision-making is required in the management of critically ill pregnant women [5] and further data is needed to guide prognostication of outcomes and clinical decision making.

We here present a case series of 14 pregnant and peripartum women with severe acute respiratory distress syndrome (ARDS) due to Covid-19 treated at our institution between January 2020 and December 2021.

Figure 1 summarizes the different ICU courses; Table 1 displays the maternal characteristics. Figure 2 displays the individual ICU course of included patients. The median maternal age was 31 years (Interquartile Range (IQR) 28–37) and the median gestational age on ICU admission 26 weeks (22–32). The median ICU length of stay was 14 days (6–34 days), 13/14 (92.8%) women had severe and 1/14 (12.5%) had moderate ARDS, the median PaO2/FiO2 (PF ratio) on admission was 74 mmHg (60–93).

10/14 (71.4%) women required invasive mechanical ventilation, 6/14 (42.8%) with additional extracorporeal membrane oxygenation (ECMO). 4/14 (28.5%) patients could be managed with non-invasive support, 3/14 (21.4%) with high flow nasal cannula (HFNC) and 1/14 (7.1%) with non-invasive ventilation (NIV). Prone positioning was used in 5/14 (35.7%) patients. Specific Covid-19 therapies included Remdesivir in 3/14 (21.4%), Tocilizumab in 5/14 (35.7%) and Glucocorticoids in 12/14 (85.7%).

7/14 (50%) women had isolated ARDS in pregnancy and another 7/14 (50%) had multi organ failure (MOF), defined by additional non-pulmonary organ specific SOFA scores ≥ 2 points. In 3/14 (21.4%) MOF developed after delivery of women with previously isolated ARDS.

Considering all MOF together, the second most common organ failure besides ARDS was circulatory failure in 10/14 (71%) women. Kidney failure was present in 5/14 (36%) women. In 4/14 (29%) there was maternal cardiac failure, 3/14 (21.4%) with predominant left heart and one right heart failure, and 2/14 (14.2%) required additional arterial ECMO cannulation for circulatory support.

None of the 7/14 (50%) patients with isolated ARDS during pregnancy died. In 3/14 (21.4%) women, caesarean section was performed while on the ICU between gestational weeks 33 and 38 due to progressive respiratory failure. These women and their offspring survived but all 3 women developed MOF after delivery. All maternal and fetal deaths occurred in patients with MOF who required high-dose catecholamine support: 2/14 (14.2%) of the women and 4/14 (28.5%) of the unborn died. Two intrauterine fetal deaths (IUFD) occurred in the setting of maternal MOF at 21 and 28 weeks’ gestation, respectively. One stillbirth occurred at gestational week 17 after maternal recovery from MOF, and one patient requested...
abortion at 30 weeks’ gestation after she had already left ICU because her child displayed severe ischemic brain damage presumably resulting from maternal MOF and profound shock.

All 7/14 (50%) women with MOF were before 28 weeks’ gestation, 3/14 (21.4%) were before gestational week 24, before viability, thus delivery was not a reasonable option. The other 4/14 (28.5%) patients with MOF were between gestational week 26 and 28. In these patients, emergency caesarean section was discussed on a daily basis within a multidisciplinary team consisting of critical care and obstetric professionals.

In summary, the management of pregnant patients with severe Covid-19 is complex and requires a multidisciplinary approach. Despite the relatively small sample size, our data suggest that patients with severe Covid-19-related ARDS can be successfully carried through pregnancy with invasive ventilation and ECMO, if needed, as long as they suffer from isolated lung failure. However, the risk of maternal and fetal death increases substantially once MOF develops. Additional circulatory failure requiring high-dose catecholamine support seems to be the major determinant of adverse maternal and fetal outcome in pregnant women with severe Covid-19 associated ARDS.

The decision regarding delivery in women with severe Covid-19 associated ARDS needs to balance multiple risks and benefits, including the risk of prematurity to the fetus, the potential to improve or worsen maternal respiratory status with delivery, and the risks accompanying major surgery such as caesarean section, particularly in patients requiring ECMO support. These preliminary
| Table 1 Patient characteristics |
|--------------------------------|
| Patient 1 | Patient 2 | Patient 3 | Patient 4 | Patient 5 | Patient 6 | Patient 7 | Patient 8 | Patient 9 | Patient 10 | Patient 11 | Patient 12 | Patient 13 | Patient 14 |
|-----------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|
| **Maternal factors** |          |          |          |          |          |          |          |          |          |          |          |          |          |
| Age (years)      | 37       | 34       | 38       | 27       | 29       | 30       | 39       | 28       | 32       | 26        | 38        | 28        | 34        | 21        |
| Weight (kg)      | 90       | 97       | 70       | 124      | 85       | 87       | 103      | 60       | 90       | 130       | 75        | 72        | 70        | 60        |
| BMI              | 29       | 34       | 27       | 44       | 32       | 33       | 39       | 23       | 35       | 42        | 27        | 29        | 26        | 22        |
| Gravida/Para     | G6/P5    | G4/P3    | G4/P3    | G1/P0    | G2/P1    | G1/P0    | G2/P1    | G1/P0    | G5/P4    | G4/P1     | G8/P3     | G1/P0     | G3/P2     | G2/P1     |
| Gestational age (admission ICU) |          |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Gestational age  | 26       | 34       | 22       | 28       | 38       | 33       | 22       | 28       | 24       | 19        | 21        | 31        | 17        | 26        |
| Comorbidities    |          |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Eclampsia        |          |          |          |          |          |          |          |          |          |           |           |           |           |           |
| HIV, hepatitis B |          |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Obesitas         |          |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Asthma           |          |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Thalassemia      |          |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Obesitas         |          |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Arterial hypertension |         |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Diabetes, arterial hypertension |         |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Pyelonephritis   |          |          |          |          |          |          |          |          |          |           |           |           |           |           |
| **Days on ICU**  | 16       | 64       | 52       | 9        | 33       | 38       | 2        | 5        | 10       | 2         | 11        | 6         | 23        | 21        |
| **Maternal Covid-19** |        |          |          |          |          |          |          |          |          |           |           |           |           |           |
| Symptom onset (days) | 8      | 6        | 4        | 8        | 9        | 7        | 5        | 10       | 9        | na        | 8         | 10        | 7         | na        |
| Covid-19 diagnosis | PCR    | PCR      | PCR      | PCR      | PCR      | PCR      | PCR      | PCR      | PCR      | PCR       | PCR       | PCR       | PCR       |
| CRP (mg/l)       | 172      | 115      | 135      | 88       | 119      | 60       | 31       | 138      | 109      | 75        | 174       | 60        | 65        | 184       |
| PCT (mcg/l)      | 0.2      | 0.2      | 0.2      | 0.2      | 0.6      | 0.7      | 0.2      | 0.3      | 0.1      | 0.1       | 0.5       | 0.8       | 0.8       | 0.6       |
| White-cell count (x 10⁻³/mm³) | 21.7   | 9.2      | 7.8      | 7.2      | 107      | 13.1     | 7.2      | 11.8     | 7.2      | 75        | 11.8      | 9.8       | 7.3       | 14.2      |
| LDH (U/l)        | 435      | 299      | 379      | 569      | 425      | 464      | 195      | 408      | 393      | 364       | 351       | 310       | 462       | 432       |
| Troponin (ng/l)  | 29       | 6        | <3.3     | na       | 4        | 5        | 4        | 4        | 9        | na        | 10        | 4         | <3.3      | 5         |
| Ferritin (mcg/l) | 193      | 76       | 94       | 337      | 179      | 201      | 43       | 99       | 151      | 221       | 171       | 105       | 749       | 290       |
| D-Dimer (mg/l)   | 3.33     | 2.01     | 1.23     | 2.26     | 1.69     | 2.63     | 1.58     | 2.5      | 0.59     | 0.69      | 1.81      | 6.39      | 0.82      | 1.02      |
| Fibrinogen (g/l) | 6.98     | 5.82     | 6.5      | 6.1      | na       | 3.9      | na       | na       | 5.79     | 6.13      | na        | 3.73      | na        | na        |
| Invasive ventilation | Yes    | Yes      | Yes      | Yes      | Yes      | Yes      | No       | No       | Yes      | No        | Yes       | No        | Yes       | Yes       |
| PEEP (plateau cm/H₂O) | 16/32   | 10/26    | 12/27    | 15/13    | 15/16    | 15/15    | n.a      | n.a      | n.a      | 16/18     | n.a       | 16/15     | n.a       | 12/16     |
| Horowitz/PF ratio | 78      | 61       | 62       | 48       | 56       | 70       | 96       | 95       | 112      | 78        | 31        | 67        | 84        | 92        |
| Patient 1 | Patient 2 | Patient 3 | Patient 4 | Patient 5 | Patient 6 | Patient 7 | Patient 8 | Patient 9 | Patient 10 | Patient 11 | Patient 12 | Patient 13 | Patient 14 |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Prone positioning during pregnancy | No | No | Yes | Yes | No | No | No | Yes | No | Yes | No | Yes | No |
| ECMO | Yes | Yes | Yes | Yes | Yes | Yes | No | No | No | No | No | No | No |
| Covid-19 targeted therapy | Remdesivir | No | Tocilizumab | No | Tocilizumab | No | No | No | No | Tocilizumab | No | Remdesivir | No |
| Systemic steroids | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No |
| Vasoactives | Yes | Yes | Yes | Yes | Yes | Yes | No | No | Yes | No | Yes | Yes | Yes |
| Aki | Yes | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | No | No |
| Dialysis | Yes | No | No | Yes | No | No | No | No | No | No | Yes | No | No |
| Heart failure | No | Yes | No | Yes | Yes | No | No | No | No | No | Yes | No | No |
| SOFA score admission | 9 | 3 | 2 | 2 | 2 | 7 | 5 | 8 | 2 | 3 | 3 |
| Maternal survival to hospital discharge | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Unborn/newborn survival to hospital discharge | No | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Abortion/stillborn | Yes | No | No | Yes | No | No | No | No | No | Yes | No | Yes | No |
| Delivery during ICU | No | C-section | C-section | C-section | C-section | C-section | No | No | No | No | Transvaginal | No | Transvaginal |

Displayed are both demographic and clinical patient characteristics of individual patients. Laboratory values and numerical indices of disease severity were recorded at critical care admission.

BMI: body mass index, G: gravida, P: para, ICU: intensive care unit, CRP: c-reactive protein, PCT: procalcitonin, LDH: lactate dehydrogenase, PEEP: positive end-expiratory pressure, PF ratio: PaO2/FiO2 ratio, ECMO: extracorporeal membrane oxygenation, AKI: acute kidney injury, SOFA: sequential organ failure assessment, MOF: multiorgan failure, ARDS: adult respiratory distress syndrome, C-section: cesarean section.
observations need to be tested in larger multicenter studies.

**Author contributions**

MB collected the data and wrote the original draft. MMH, CK, TS and KS reviewed and edited the manuscript. All authors read and approved the final manuscript.

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**Availability of data and materials**

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval and consent to participate**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.

**Fig. 2** Individual ICU course of included patients. We assessed the use of vasoactive agents for more than 1 day in patients unresponsive to volume challenge as circulatory failure. We distinguished high dose (> 0.1 mcg/kg/min) from low dose catecholamines (< 0.1 mcg/kg/min). Acute kidney injury (AKI) was diagnosed according to the Acute Kidney Injury Network (AKIN) classification. An isolated and marginally elevated bilirubin was not assessed as sign of liver failure and low platelets under ECMO-therapy were not considered to be organ failure, since both had likely other confounders. HFNC high flow nasal canula, NIV noninvasive ventilation, ITN intubation, ARDS adult respiratory distress syndrome, ECMO extracorporeal membrane oxygenation, H high dose catecholamines

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