Lampiran 1

LEMBAR KONSULTASI

Nama : Dewi Suviya Mulyani

Nim : P27820418053

Judul : Literatur Riview Pengaruh Posisi Tengkurap Pada Pasien Covid-19

No	Hari /Tgl	Materi Bimbingan	Revisi	TTD Mahasiswa	TTD Dosen
1.	Sabtu, 06 Februari 2021	1. Arahan penyusunan proposal KTI 2. Kontrak prosedur bimbingan			
2.	Sabtu, 13 Februari 2021	BAB 1	1. Memberi awalan judul literatur riview atau studi literatur 2. Mengganti tujuan umum dan tujuan khusus		
3.	Jumat, 11 Maret 2021	BAB 2	Ditambahkan indikasi teknik posisi tengkurap		
4.	Kamis, 11 Maret 2021	BAB 3	1. Setiap tabel diberi nomor dan nama tabel 2. Jurnal pada diagram flow diganti jumlah yang dibaca saja 3. Mengecek ulang apakah jurnal terakreditasi		

5.	Senin, 22 Maret 2021	Penulisan Proposal	1. Daftar pustaka dilengkapi serta penulisan link diganti warna biru 2. Spasi di ganti 2 pt 3. Penulisan lembar pengesahan dirubah		
6.	Senin, 29 Maret 2021	Arahan persiapan seminar Proosal	-		
7.	Jumat, 30 April 2021	1. Arahan penyusunan BAB 4,5,6 2. Kontrak prosedur bimbingan	-		
8.	Senin, 03 Mei 2021	BAB 4 Hasil	1. Membuat tabel jurnal 2. Mengganti jurnal yang kurang sesuai 3. Memberikan konsep cara menganalisis jurnal 4. Merevisi proposal sebelumnya		
9.	Rabu, 05 Mei 2021	BAB 4 Analisis	1. Tambahan poin pada analisis		
10.	Kamis, 20 Mei 2021	BAB 5 Pembahasan	1. Revisi kata yang diperlukan 2. Menambahkan opini penulis		
11.	Kamis, 17 Mei 2021	BAB 5 Pembahasan	1. Menambahkan teori oleh buku, jurnal, atau pengalaman penulis 2. Menambahhkan keterbatasan		

12.	Senin, 24 Mei 2021	Abstrak dan BAB 6 Penutup	1. Revisi kata yang salah 2. Pada metode ditambahkan rincian jurnal 3. San diganti sesuai dengan manfaat		

Lampiran 2

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Politeknik Kesehatan Kemenkes Surabaya
Program Studi D3 Keperawatan Sidoarjo
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Catatan Perbaikan Seminar Proposal KTI
Prodi D3 Keperawatan Sidoarjo
Tahun Akademik 2020/2021

NAMA MAHASISWA : Dewi Suviya Mulyani

NIM : P27820418053

JUDUL KTI : STUDI LITERATUR PENGARUH POSISI TENGKURAP TERHADAP PENINGKATAN SATURASI OKSIGEN PADA PASIEN COVID-19

NO	REVISI	TANDA TANGAN PENGUJI
1.	Loetfia Dwi Rahariyani, S.Kp., M.Si Revisi : 1. Penulisan NIM diganti 2. Tujuan umum pada Rumusan masalah diganti ditambahi ditinjau dari studi literatur serta pada tujuan khusus kata “efektifitas” di ganti dengan kata “pengaruh” sesuai judul 3. Penambahan indikasi, kontraindikasi dan cara melakukan posisi tengkurap pada pasien 4. Revisi kriteria inklusi dan eksklusi penambahan usia, indikator kenaikan saturasi oksigen, batasan minimal saturasi oksigen, penggunaan alat bantu	
2.	Kusmini Suprihatin, M.Kep, Sp.An Revisi : 1. Pada kriteria inklusi eksklusi Karakter pasien disesuaikan dan penggunaan alat bantu pasien disamakan 2. Penulisan daftar isi, daftar lampiran, dan dftar tabel diganti 3. Tabel potrait pada bab 3 diganti landscape	

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Lampiran 3

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Politeknik Kesehatan Kemenkes Surabaya
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Catatan Perbaikan Seminar Hasil KTI
Prodi D3 Keperawatan Sidoarjo
Tahun Akademik 2020/2021

NAMA MAHASISWA : Dewi Suviya Mulyani

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JUDUL KTI : STUDI LITERATUR PENGARUH POSISI TENGKURAP TERHADAP PENINGKATAN SATURASI OKSIGEN PADA PASIEN COVID-19

NO	REVISI	TANDA TANGAN PENGUJI
1.	Loetfia Dwi Rahariyani, S.Kp., M.Si Revisi : 1. Penulisan abstrak dan Cover diganti sesuai ketentuan diskusikan dengan kelompok bimbingan 2. Pada 4.2.3 setiap jurnal dibuat diagram atau table dijelaskan pronasi sesuai masing masing jurnal 3. Jelaskan Spo2 yang bagaimana berapa kenaikannya dan presentasenya 4. Kesimpulan dijelaskan sesuai jurnal tidak boleh menggunakan kesimpulan pribadi 5. Seluruh table menggunakan portrait bukan landscape	
2.	Kusmini Suprihatin, M.Kep, Sp.An Revisi : 1. focus pada tujuan khusus untuk mengisi pembahasan dan hasil 2. pada kesimpulan merangkum tujuan khusus bukan hal lain 3. pada kesimpulan sudah tidak bicara angka namun hasil kesimpulan seluruh jurnal sesuai tujuan khusus	

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Lampiran 4

ORIGINAL ARTICLE

Awake Prone Positioning in COVID-19 Patients

Prabhanjan Singh[1], Prerana Jain[2], Himanshu Deewan[3]

Abstract

Background: WHO has declared SARS-CoV-2 as pandemic. Patients with COVID-19 present mainly with respiratory symptoms. Prone position has been traditionally used in acute respiratory distress syndrome (ARDS) to improve oxygenation and prevent barotrauma in ventilated patients. Awake proning is being used as an investigational therapy in COVID to defer invasive ventilation, improve oxygenation, and outcomes. Hence, we conducted a retrospective case study to look for benefits of awake proning with oxygen therapy in non-intubated COVID patients.

Materials and methods: A retrospective case study of 15 COVID patients admitted from June 15 to July 1, 2020 to HDU in our hospital was conducted. Co-operative patients who were hemodynamically stable and $SpO_2 < 90\%$ on presentation were included. Oxygen was administered through facemask, non rebreathing mask and non invasive ventilation to patients as per requirement. Patients were encouraged to maintain prone position and target time was 10–12 hours/day. SpO_2 and P/f ratio in supine and prone position was observed till discharge. Primary target was $SpO_2 > 95\%$ and P/f > 200 mm Hg. Other COVID therapies were used according to institutional protocol.

Results: The mean SpO_2 on room air on admission was 80%. In day 1 to 3, the mean P/f ratio in supine position was 98.8 ± 29.7 mm Hg which improved to 136.6 ± 38.8 mm Hg after proning ($p = 0.005$). The difference was significant from day 1 to 10. Two patients were intubated. The mean duration of stay was 11 days.

Conclusion: Awake prone positioning showed marked improvement in P/f ratio and SpO_2 in COVID-19 patients with improvement in clinical symptoms with reduced rate of intubation.

Highlights:

- Prone position ventilation improves oxygenation by reducing VQ mismatch.
- Awake prone positioning has been used along with high-flow oxygen therapy in recent pandemic of SARS-CoV-2 virus for management of mild to moderate cases.

Keywords: Awake prone position, Coronavirus, COVID-19, SARS-CoV-2.

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Introduction

A novel strain of coronavirus SARS-CoV-2 started from China has now spread to over 200 countries across the world.[1,2] This has been declared as pandemic by the WHO.[3] COVID-19 is primarily a respiratory illness. The symptoms of COVID-19 are from mild flu-like illness to severe acute respiratory distress syndrome (ARDS)-like requiring mechanical ventilation.[2,3] The COVID-19 patients often present with low oxygen saturation requiring supplemental oxygen. However, absence of dyspnea and tachycardia is seen aptly described as "happy hypoxia".[4–6]

Prone ventilation is a recommended recruitment strategy in ARDS for many years in intubated patients.[7–9] In recent time, awake prone position therapy has come up with great benefits. This technique improves oxygenation and decreases the need for invasive ventilation.[10,11] With the global pandemic putting a strain on many countries' resources, a high-flow oxygen therapy with awake prone position seems to be of low risk, easy to perform, and low cost management strategy in non-intubated patients.[11] So, we conducted a retrospective observational study in high-dependency unit (HDU) in our hospital to see the effect of awake prone position therapy in COVID-19 patients.

Materials and Methods

Approval for the study and a waiver of the consent was obtained from the institutional ethics committee. This case series describes 15 patients with COVID-19 pneumonia requiring oxygen supplementation admitted from June 15 to July 1, 2020 in HDU in our hospital. All patients were diagnosed with COVID-19 disease by RT-PCR (real time-polymerase chain reaction) technique. Patients who were hemodynamically stable, SpO_2 <90% on presentation, and able to adjust their prone position were included in the study. Those who were hemodynamically unstable, drowsy, or uncooperative were excluded from the study.

Continuous vital signs [electrocardiogram (ECG), SpO_2, non invasive blood pressure (NIBP), respiratory rate, and temperature] were monitored. Intra-arterial line was inserted for frequent arterial blood gas measurement to monitor PaO_2/fiO_2 (P/f) ratio.

Oxygen therapy was initiated with face mask at 5 L/minute and the flow rate was titrated to reach the target SpO_2 >94%. If the target SpO_2 was not achieved then non-rebreathing mask (NRBM) at 10 to 15 L/minute was considered. Non-invasive ventilation (NIV) was started if respiratory distress worsened or hypoxemia not alleviated by standard oxygen therapy. Tracheal intubation and invasive ventilation were considered when the patient deteriorated, i.e., altered sensorium, hypotension, or shock.

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Conflict of interest: None

Awake prone position was explained to every patient and they were encouraged to spend as much time in prone position as they could tolerate. The target time in prone position was 10 to 12 hours per day. Proning was performed 1 hour after meals to avoid gastrointestinal side effects. Specific COVID-19 treatment was given to all patients according to the institutional protocol which included remdesivir, tocilizumab, dexamethasone, and low-molecular weight heparin. Target for discharging from HDU was SpO_2 of >95% and P/f ratio of >200 mm Hg. Patients were shifted to ward when they were weaned off oxygen at least for 24 hours.

Results

The mean age of the sample was 51.5 years. Eight patients had a history of systemic comorbidities like diabetes (DM) and hypertension (Htn). Only 6 patients out of 15 presented with tachypnea despite low SpO_2 depicting the phenomenon of "silent hypoxemia" (Table 1).

The mean SpO_2 on room air on admission was 80%. Oxygen therapy was started immediately through face mask to four patients (26.6%), NRBM to five patients (33.3%), and NIV to six patients (40%). Thirteen patients were successfully weaned off in mean duration of 10 days and were discharged to ward. Rest two (13%) required invasive positive pressure ventilation (IPPV) and were shifted to intensive care unit (ICU) (Fig. 1).

SpO_2 improved as soon as oxygen therapy was started. A further rise in SpO_2 was seen with change in the position from supine to prone owing to the reduction in intrapulmonary shunting. This increasing SpO_2 trend with prone positioning was seen in all patients (Table 2).

In first 3 days, the mean P/f ratio in supine position was 98.8 ± 29.7 mm Hg which improved to 136.6 ± 38.8 mm Hg after proning (p value = 0.005). Similar trend was observed over next days where mean P/f ratio in supine position were 142.4 ± 40.9, 178.3 ± 38.3, and 210.3 ±37.9 which increased to 173.9 ± 46.6, 214.8 ± 44.2, and 218.6 ± 32.5 from day 4 to 6, day 7 to 10, and day 11 to till discharge, respectively (p value = 0.050, 0.033, and 0.692). The difference was significant in the initial days from day 1 to day 10. However, this

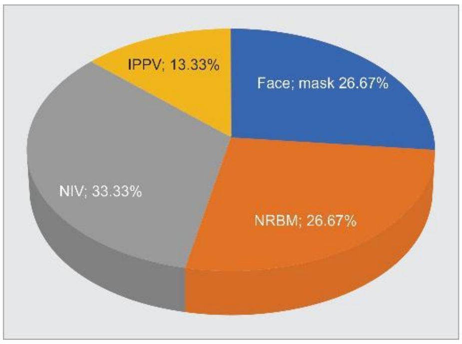

Fig. 1: Modes of oxygen therapy used for COVID-19 patients

Table 1: Overview of cases

Case no.	*Age/gender*	*Comorbidities*	*Room air SpO_2 (%)*	*Tachypnea*	*Mode of oxygen therapy*	*Duration of HDU stay (days)*	*Intubation required*	*Outcome*
1	48/M	–	76	Absent	NRBM @ 15 L/minute	10	No	Discharged to ward
2	53/M	DM, Htn	72	Absent	NRBM @ 15 L/minute	13	No	Discharged to ward
3	59/M	DM	84	Absent	NRBM @ 10 L/minute f/b NIV f/b IPPV	20	Yes	Expired on D_{20}
4	57/M	DM, Htn, obesity	79	Absent	NRBM @ 15 L/minute	6	No	Discharged to ward
5	58/M	DM	67	Present	NIV @ 0.8 FiO_2	9	No	Discharged to ward
6	73/M	DM, Htn	72	Present	NIV @ 0.7 FiO_2	12	No	Discharged to ward
7	58/M	–	88	Present	NIV @ 0.8 FiO_2	15	No	Discharged to ward
8	54/M	DM	80	Present	NIV @ 0.9 FiO_2 f/b IPPV	22	Yes	Expired on D_{22}
9	57/M	–	90	Present	NIV @ 0.6 FiO_2	14	No	Discharged to ward
10	39/M	–	94	Absent	Face mask @ 10 L/ minute	3	No	Discharged to ward
11	47/F	–	68	Present	NIV @ 0.9 FiO_2	8	No	Discharged to ward
12	67/M	DM	87	Absent	Face mask @ 5 L/ minute	10	No	Discharged to ward
13	34/M	–	67	Absent	NRBM @ 15 L/minute	7	No	Discharged to ward
14	37/M	DM	85	Absent	Face mask @ 10 L/ minute f/b NRBM @ 15 L/minute	10	No	Discharged to ward
15	32/M	–	89	Absent	Facemask @ 8 L/ minute	7	No	Discharged to ward
Mean ± SD	51.5 ± 11.9	–	80 ± 0.09	–	–	10 ± 5.13	–	–

Table 2: Median SpO_2 (%) with oxygen therapy in supine and prone positions

On presentation		*Median SpO_2 (%) with oxygen therapy (Interquartile range in parenthesis)*							
		Day 1–3		*Day 4–6*		*Day 7–9*		*Day 10–till discharge*	
Cases	*Room air SpO_2 (%)*	*Supine positon*	*Prone position*	*Supine positon*	*Prone position*	*Supine positon*	*Prone position*	*Supine positon*	*Prone position*
Case 1	76	93 (88–94)	96 (93–97)	94 (92–96)	96 (94–97)	95 (96–98)	97 (96–99)	97 (97–99)	97 (96–99)
Case 2	72	92 (86–94)	95 (92–97)	92 (89–95)	95 (93–97)	94 (93–96)	96 (95–98)	98 (97–100)	99 (98–100)
Case 3	84	88 (85–92)	91 (88–93)	88 (87–90)	90 (88–91)	87 (86–94)	90 (89–96)	–	–
Case 4	79	89 (88–93)	92 (88–94)	93 (92–95)	95 (93–96)	96 (94–97)	97 (95–99)	–	–
Case 5	67	85 (82–90)	89 (86–91)	87 (85–90)	90 (88–92)	92 (91–94)	95 (94–98)	–	–
Case 6	72	89 (84–92)	92 (90–94)	91 (89–93)	93 (92–94)	93 (92–95)	94 (93–96)	96 (95–98)	98 (96–99)
Case 7	88	92 (89–95)	95 (93–96)	93 (90–94)	95 (94–96)	95 (94–97)	97 (96–99)	98 (95–99)	98 (97–99)
Case 8	80	87 (84–91)	89 (87–91)	–	–	–	–	–	–
Case 9	90	94 (90–96)	96 (93–97)	95 (93–96)	97 (95–98)	98 (97–99)	99 (97–100)	–	–
Case 10	94	96 (95–98)	98 (94–98)	99 (98–100)	99 (98–100)	–	–	–	–
Case 11	68	89 (84–90)	93 (90–94)	92 (89–93)	95 (93–96)	97 (96–99)	99 (97–100)	–	–
Case 12	87	91 (88–94)	94 (91–95)	93 (91–95)	96 (94–97)	95 (94–96)	97 (96–99)	97 (96–99)	98 (97–100)
Case 13	67	88 (85–92)	93 (90–94)	92 (90–94)	95 (92–96)	97 (96–99)	99 (98–99)	–	–
Case 14	85	90 (87–94)	94 (89–95)	93 (92–96)	96 (93–97)	96 (95–98)	97 (95–99)	98 (97–100)	99 (97–100)
Case 15	89	92 (90–95)	95 (92–96)	94 (92–95)	97 (96–98)	99 (98–100)	99 (97–100)	–	–

difference was insignificant after 10 days till the time of discharge (Table 3). The mean duration of stay was 10 days in HDU (Fig. 2).

Only 2 patients out of 15 required intubation in view of progressing disease or deteriorating consciousness who were excluded from the study.

Discussion

COVID-19 pneumonia is a specific disease whose distinctive features are severe hypoxemia often associated with near normal respiratory system compliance.[12] Hence, an unusual phenomenon of "happy hypoxia" or "silent hypoxemia" is seen in many patients.[5,6] Patients appear to be normally functioning without dyspnea and tachycardia despite being hypoxemic.

Patients with severe disease often require high oxygenation support. High-flow oxygen therapy and noninvasive positive pressure ventilation have been used. Some patients may develop ARDS and warrant invasive ventilation.[13] Hence, any therapy which can improve oxygenation and reduce lung injury should be used to improve the survival rate.

The initial approach for managing such patients was to intubate early to decrease the work of breathing and prevent patient self-inflicted lung injury (P-SILI).[12,14] Later on, it was found that the complications and mortality were high with this approach.[15,16] Moreover, during the pandemic time, it led to resources and manpower crisis, especially in developing nations.

The role of prone position ventilation is well established in classical ARDS.[8] In prone position, there is hemogeneous distribution of the gas which reduces the ventilation-perfusion (VQ) mismatch. This reduces the intrapulmonary shunt and opens the atelectatic lung areas with adequate sputum drainage, improving oxygenation.[7,9] Also, the transpulmonary pressure gradient is reduced which decreases barotrauma.[9]

In recent studies, awake prone positioning was used in emergency department and ward settings to maintain oxygenation of COVID-19 patients.[17,18] Studies have shown to avoid intubation with early application of prone positioning with high-flow nasal cannula (HFNC) in moderate ARDS patients.[19–21] In our study, we also found that the median P/f ratio significantly improved from supine to prone position from day 1 to day 10. We were able to reduce the intubation rates, avoid the problems related to invasive ventilation and with use of sedation and neuromuscular blockers. The mean duration of stay was 10 days in HDU. Two out of 15 patients who required intubation were shifted to ICU and subsequently expired.

Most patients tolerated the prone position well and reported the improvement in symptoms. We are also cognizant that other COVID-19 therapies could have modified the disease course as well.[22–25] Hence, awake proning with high-flow oxygen therapy proved to be a low risk, easy to perform, easily tolerated, and low cost rescue therapy in COVID-19 patients.

Limitations

- There was no randomization to a control group.
- Sample size of the study was small.
- High-flow nasal cannula was not available in our set up which is highly recommended.

Conclusion

Awake prone positioning showed marked improvement in P/f ratio and SpO_2 in COVID-19 patients with improvement in clinical symptoms and minimal complications. We were able to reduce the intubation rates which helped in offloading the resource and manpower burden on healthcare system in pandemic.

Table 3: Average P/f ratio in supine and prone positions

	Average P/f ratio (mm Hg)	*Case 1*	*Case 2*	*Case 3*	*Case 4*	*Case 5*	*Case 6*	*Case 7*	*Case 8*	*Case 9*	*Case 10*	*Case 11*	*Case 12*	*Case 13*	*Case 14*	*Case 15*	*Mean ± SD*	*p value*
Day 1–3	Supine position	84.2	125.5	67.9	65.7	68.5	91.7	77.4	83.1	163.3	142.7	80.8	88.9	100.7	112.3	130.5	98.8 ± 29.7	0.005
	Prone position	170.5	170.4	120.6	85.8	108.8	116.8	98.3	96.7	171.4	213.3	100.6	105.7	175.4	152.6	162.8	136.6 ± 38.8	
Day 4–6	Supine position	170.1	101.3	100.5	147.6	123.6	125.4	87.6	Intubated on day 3	151.4	220.6	104.5	130.4	170.8	182.6	157.4	140.9 ± 37.4	0.050
	Prone position	234.2	122.3	120.9	157.7	148.8	152.8	115.6		206.2	278.4	164.5	153.3	182.5	215.7	182.2	173.9 ± 46.6	
Day 7–9	Supine position	250.4	158.8	118.8	212.5	154.2	140.6	130.7	–	204.7	–	190.3	154.8	194.6	210.5	197.5	178.3 ± 38.3	0.033
	Prone position	305.7	190.8	156.9	245.6	216.2	180.5	151.6	–	250.6	–	225.8	168.8	230.5	251.8	217.8	214.8 ± 44.2	
Day 10–till discharge	Supine position	270.4	190.2	Intu-bated on day 10	–	–	212.5	160.8	–	–	–	–	195.2	–	232.7	–	210.3 ± 37.9	0.692
	Prone position	280.2	220.4		–	–	230.7	180.4	–	–	–	–	220.6	–	240.7	–	218.6 ± 32.5	

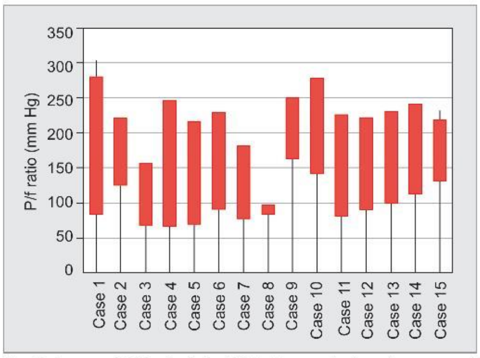

Fig. 2: Range of P/f ratio in individual cases during the course of treatment

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ORIGINAL ARTICLE
COVID-19

Self-proning in COVID-19 patients on low-flow oxygen therapy: a cluster randomised controlled trial

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ABSTRACT

Rationale and objectives: Prone positioning as a complement to oxygen therapy to treat hypoxaemia in coronavirus disease 2019 (COVID-19) pneumonia in spontaneously breathing patients has been widely adopted, despite a lack of evidence for its benefit. We tested the hypothesis that a simple incentive to self-prone for a maximum of 12 h per day would decrease oxygen needs in patients admitted to the ward for COVID-19 pneumonia on low-flow oxygen therapy.

Methods: 27 patients with confirmed COVID-19 pneumonia admitted to Geneva University Hospitals were included in the study. 10 patients were randomised to self-prone positioning and 17 to usual care.

Measurements and main results: Oxygen needs assessed by oxygen flow on nasal cannula at inclusion were similar between groups. 24 h after starting the intervention, the median (interquartile range (IQR)) oxygen flow was 1.0 (0.1–2.9) $L \cdot min^{-1}$ in the prone position group and 2.0 (0.5–3.0) $L \cdot min^{-1}$ in the control group (p=0.507). Median (IQR) oxygen saturation/fraction of inspired oxygen ratio was 390 (300–432) in the prone position group and 336 (294–422) in the control group (p=0.633). One patient from the intervention group who did not self-prone was transferred to the high-dependency unit. Self-prone positioning was easy to implement. The intervention was well tolerated and only mild side-effects were reported.

Conclusions: Self-prone positioning in patients with COVID-19 pneumonia requiring low-flow oxygen therapy resulted in a clinically meaningful reduction of oxygen flow, but without reaching statistical significance.

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This randomised controlled trial analysed the effect of self-prone positioning in #COVID 19-associated pneumonia. Prone positioning was easy to implement and oxygen needs were lower in the self-prone group, although not reaching statistical significance. https://bit.ly/2MdFeyX

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Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)-associated pneumonia is associated with severe hypoxaemic respiratory failure requiring treatment in high-dependency or intensive care units (ICUs) in ∼5–10% of hospitalised patients [1, 2]. Given the rapid increase of cases during the recent pandemic, many high-dependency units and ICUs have been overwhelmed in their capacity to provide care [1, 3]. In addition, several pharmacological agents for the treatment of SARS-CoV-2-associated pneumonia remain of uncertain benefit or have been associated with potentially life-threatening side-effects [4]. In patients hospitalised in a medical ward with a diagnosis of coronavirus disease 2019 (COVID-19) pneumonia, any simple intervention to limit the progression of hypoxaemia and avoid transfers of patients to critical care units for mechanical ventilation may be of benefit for the management of hospital resources.

Lung-protective mechanical ventilation and intermittent prone positioning with neuromuscular blockade are standard care and evidence-based strategies in the management of severe acute respiratory distress syndrome (ARDS) [5–7]. Use of low tidal volume ventilation (4–8 $mL \cdot kg^{-1}$ of predicted weight) targeting a plateau pressure <30 cmH_2O, with high positive end-expiratory pressure and prone mechanical ventilation for 12–16 $h \cdot day^{-1}$ has been integrated into the Surviving Sepsis Campaign guidelines for the management of critically-ill adults with COVID-19 [8]. The rationale behind the prone position is to reduce ventilation/perfusion mismatch and thus hypoxaemia. The prone position decreases the pleural pressure gradient between dependent and nondependent lung regions, which is believed to generate a more homogeneous lung ventilation in ARDS patients [9]. As the prone position does not appear to alter blood flow distribution, a subsequent reduction in shunting might be observed [10].

At present, no published trials have documented the effect of the prone position in awake patients with COVID-19 pneumonia. Case series suggest that the prone position in awake patients treated with high-flow nasal oxygen therapy or noninvasive ventilation is feasible, easier to perform than in heavily sedated, more severely ill patients, and is not associated with major side-effects [11–16]. However, it remains unknown whether prolonged periods of prone position in patients admitted for COVID-19 pneumonia on low-flow oxygen therapy are associated with a persistent improvement in peripheral oxygen saturation (S_{pO_2}) and lower needs of oxygen. We designed this single-centre, cluster randomised controlled trial to test the hypothesis that the prone position is associated with lower needs of oxygen in patients admitted to the medical ward for COVID-19 pneumonia.

Methods

Study design and participants

We conducted a single-centre cluster randomised controlled trial in six medical wards in Geneva University Hospitals (Geneva, Switzerland). As the intervention (incentive to self-prone) was not blinded and delivered by physicians and nurses involved in patient monitoring during the COVID-19 pandemic, a cluster randomised controlled trial design was chosen to minimise contamination between groups (*i.e.* to prevent patients in the control group from receiving the intervention if admitted to the same ward as those in the intervention group). Inclusion criteria were patients aged ⩾18 years admitted to a medical ward for treatment of COVID-19 pneumonia with low-flow oxygen therapy (defined as 1–6 $L \cdot min^{-1}$) through nasal cannulas to obtain a S_{pO_2} level of 90–92%. Exclusion criteria were patients initially treated in the ICU or high-dependency unit and recovering from ARDS; those with oxygen needs >6 $L \cdot min^{-1}$ using a nasal cannula or with >40% inspiratory oxygen fraction (F_{iO_2}) using a Venturi mask to obtain a S_{pO_2} level of 90–92%; pregnant women; terminally ill patients; and those unable to self-prone. Patients were screened by a daily review of admissions to each ward.

Randomisation

The randomisation unit was a medical ward in the division of internal medicine of our hospital with a 15-bed capacity. Six clusters were selected and a computer-generated randomisation scheme was used to assign each medical ward randomly in a 1:1 ratio to either the intervention or usual care. After April 14, 2020, most wards dedicated to the care of COVID-19 pneumonia gradually closed because of effective COVID-19 containment measures and a favourable evolution of the epidemic in our region. Four more patients were individually randomised by the computer-generated programme in the wards which remained open. From 25 April to 29 May 2020, no further eligible patients were admitted to the ward for COVID-19 pneumonia and we decided to close enrolment, despite not having reached the number required by our sample size calculation.

Intervention

We compared an add-on to usual care *versus* usual care alone. Usual care consisted of 1) oxygen titration with nasal cannula according to our institutional recommendations to target S_{pO_2} values between 90% and

94%. Nurses carried out at least six routine rounds per 24 h to monitor oxygen needs and adapt oxygen flow to the prescribed S_{pO_2} target; 2) empirical antibiotics for community-acquired pneumonia; 3) an association of hydroxychloroquine and lopinavir/ritonavir as proposed by our institutional guidelines; and 4) a restrictive fluid strategy. Regarding the intervention, an intern (CC) and a resident (AK) from the division of lung diseases promoted self-proning for 12 h per day as an addition to usual care for 24 h. After an initial demonstration with the study investigators, all patients were given an explanatory brochure with photographs of the prone position and it was suggested that they use their mobile phone "timer" function to alternate their body position every 4 h. Nurses regularly visited patients to encourage them to change their bed position during their rounds. Vital signs were recorded after 24 h and patients answered a brief survey on tolerance and estimated time of prone positioning.

Data collection and study outcomes

Oxygen flow ($L \cdot min^{-1}$), estimated F_{iO_2} (%), S_{pO_2}, respiratory rate and heart rate were retrieved directly from the institutional electronic patient health record. Transfers to critical care units or home discharge were recorded. Time spent in the prone position was self-reported in a diary. S_{pO_2} and other vital signs were recorded at 24 h when the patient was supine at rest for 1 h. S_{pO_2} was recorded after its value had stabilised for ⩾1 min. The pre-specified primary outcome was oxygen needs assessed by nasal cannula oxygen flow at 24 h. Secondary outcomes were the S_{pO_2}/F_{iO_2} ratio (defined as S_{pO_2} percentage divided by the F_{iO_2}) at 24 h [17], respiratory and heart rate at 24 h, patient trajectory (transfer to critical care unit) and potential intervention-related adverse effects as defined by neck pain, position-related discomfort and gastro-oesophageal reflux.

Statistical analyses

Continuous variables were summarised as medians and interquartile ranges (IQR) and categorical variables as numbers and percentages. Differences between groups were assessed using the Mann–Whitney–Wilcoxon test for continuous outcomes.

Sample size estimate

We based our sample size estimation on a preliminary unpublished observation in 20 patients admitted to the respiratory wards for COVID-19 pneumonia on low-flow oxygen therapy. In these patients, prone position for 15 min was associated with an immediate improvement in S_{pO_2}, allowing a decrease in oxygen flow by 1 $L \cdot min^{-1}$ with a standard deviation of 1 $L \cdot min^{-1}$. Flow meters used in our institution for oxygen therapy allow oxygen flow to be read with a precision of 0.5 $L \cdot min^{-1}$. Additionally, we considered that a treatment effect of 1 $L \cdot min^{-1}$ would be clinically relevant for triage strategies in an overwhelmed healthcare system. To show a difference of 1 $L \cdot min^{-1}$ of oxygen flow with a standard deviation of 1 $L \cdot min^{-1}$ in an individually randomised trial with a two-sided significance level of 0.05 and a power of 0.8, enrolment of 32 patients would be needed. To take into account the correlation between patients of the same medical ward, the sample size was multiplied by a design effect of 2.4 corresponding to an intraclass correlation coefficient of 0.1 and a number of patients per ward equal to 15. Therefore, enrolment of 76 patients would have been required.

Analyses were performed with R statistical language [18].

Ethics

The institutional ethics review committee approved the trial (CCER 2020–00705). The study was registered on the Swiss National Clinical Trial portal (SNCTP000003718). All participants provided written informed consent before screening.

Results

Seven medical wards were approached to participate in the trial and six wards were randomised in a 1:1 ratio to the intervention or usual care. From April 6 to April 25, 2020, 54 patients were screened and 27 were enrolled in the trial. Causes for noninclusion were 1) refusal to participate (n=19) and 2) impossibility of self-proning due to morbid obesity, hemiplegia or cervical minerva (n=5); and 3) end-of-life support care (n=3). 10 patients were randomised to self-prone and 17 to usual care (figure 1). Baseline characteristics are described in table 1. Mean±SD age of participants was 58±12 years; 10 (37%) out of 27 were female. Among the participants, 12 (44%) out of 27 had hypertension, five (19%) out of 27 had diabetes, and one patient had chronic kidney disease. Time from first symptoms to inclusion was 10.5±5.1 days.

Estimated self-prone time was 295±216 min in the self-prone group and 7±29 min in the control group (due to a single patient who spent an estimated time of 120 min in the position). At baseline, median (IQR) oxygen flow on a nasal cannula was 2.5 (2.0–3.0) $L \cdot min^{-1}$ in the self-prone group and 2.0 (1.0–

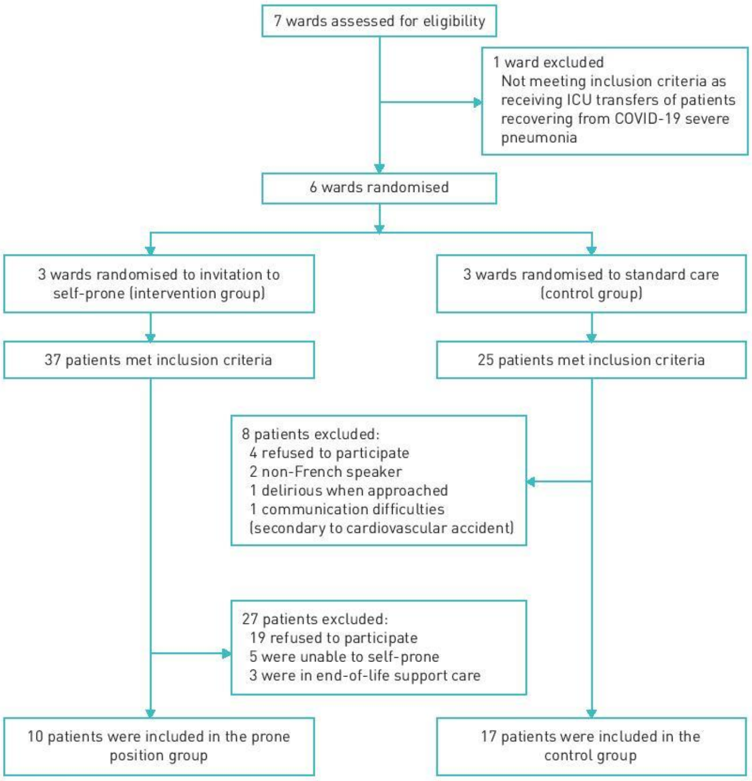

FIGURE 1 Study flowchart. ICU: intensive care unit; COVID-19: coronavirus disease 2019.

TABLE 1 Clinical characteristics of the study population

	Whole population	Self-proning	Usual care
Patients	27	10	17
Male	17 (63)	6 (60)	11 (65)
Age years	58±12	54±14	60±11
Body mass index kg·m^{-2}	28.2±4.7	29.7±5.3	27.3±4.2
Comorbidities			
Hypertension	12 (44)	3 (30)	9 (53)
Diabetes	5 (19)	2 (20)	3 (18)
Chronic kidney disease	1 (4)	0	1 (6)
Self-reported heart disease	0	0	0
COPD	0	0	0
Time onset of symptoms until inclusion days	10.5±5.1	10.6±5.1	10.5±5.3
Treatment received			
Azithromycin	2 (7)	1 (10)	1 (6)
Hydroxychloroquine	19 (70)	6 (60)	13 (77)
Lopinavir/ritonavir	15 (56)	5 (50)	10 (59)

Data are presented as n, n (%) or mean±SD.

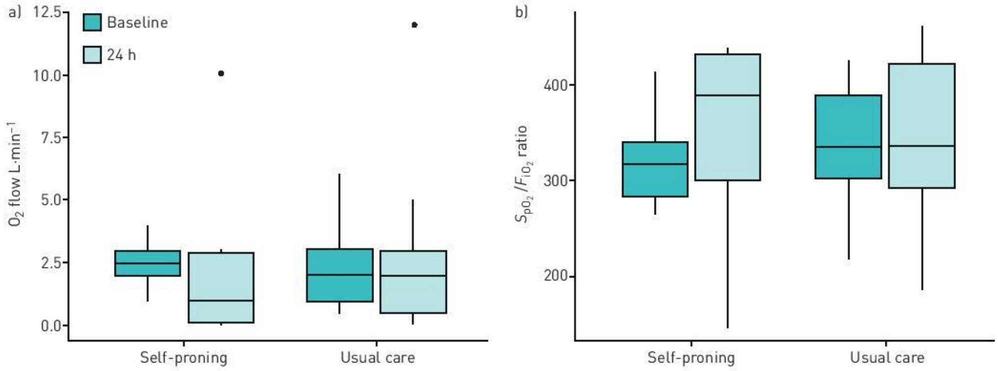

FIGURE 2 a) Oxygen (O_2) flow on nasal cannula in the self-proning group and in the control group; b) peripheral oxygen saturation (S_{pO_2})/ inspiratory oxygen fraction (F_{IO_2}) ratio in the self-proning group and in the control group. Data are presented as median, interquartile range and 90th and 10th percentile.

3.0) L·min^{-1} in the control group. At 24 h, median (IQR) oxygen flow was 1 (0.1–2.9) L·min^{-1} in the self-prone position group and 2.0 (0.5–3) L·min^{-1} in the control group (p=0.507). This corresponded to a median (IQR) S_{pO_2}/F_{IO2} ratio of 390 (303–432) in the self-prone group at 24 h compared to 336 (294–423) in the control group (p=0.633) (figure 2). Changes of oxygen flow and S_{pO_2}/F_{iO_2} ratio for individual patients are shown in supplementary figure 1A and B). Main and secondary physiological end-points are presented in table 2. Median respiratory rate decreased with the intervention, whereas no effect was observed for heart rate. One patient randomised to the self-prone position was admitted to the high-dependency unit because of increased oxygen needs *versus* none in the usual care group. This patient was a 45-year-old male with a body mass index of 27.8 kg·m^{-2} without known comorbidities. He had an estimated prone position time of 6 min over 24 h and a reported side-effect of mild discomfort. Five (50%) other patients in the intervention group reported intervention-related adverse events, mainly mild position-related discomfort. No other intervention-related side-effects were reported.

Discussion

In this cluster randomised trial, self-prone positioning in patients admitted for COVID-19 pneumonia requiring low-flow oxygen therapy appeared to be effective in decreasing oxygen needs at 24 h. A clinically meaningful reduction of oxygen flow and an improved S_{pO_2}/F_{iO_2} ratio were observed, although they did not reach statistical significance. With an unprecedented number of ill patients in a small geographical area and the risk of overwhelming local health resources, a reduction of oxygen flow by 1 L·min^{-1} could be of importance to select stable patients for home discharge with an oxygen supply or to prevent unnecessary or premature transfers to intermediate care units.

The intervention consisted of a simple incentive to self-prone for 12 h over a period of 24 h. Invitation to self-prone was easy to implement after an initial demonstration and distribution of an explanatory brochure and resulted in a substantial time spent in this position. The intervention was well tolerated and only mild adverse events were reported. Our results are in line with published case series and expand current knowledge on the prone position in awake patients with hypoxaemic respiratory failure associated with COVID-19 pneumonia [12–16]. Prone positioning is believed to improve hypoxaemia by generating a more homogeneous lung ventilation without altering blood flow distribution [9, 10], as illustrated by data from our trial.

In this unique pandemic situation, health professionals have often been forced to provide immediate medical assistance rather than generating reliable data from randomised trials to inform clinical practice. Awake prone positioning has been widely adopted by physicians around the globe [19] and proposed in conscious COVID-19 patients by the UK Intensive Care Society, but without strong evidence [20]. Such a recommendation may discourage the scientific community to run trials, although most professional bodies emphasise the need for higher quality evidence [21, 22]. Therefore, we specifically focused this randomised trial on a selected population of nonsevere COVID-19 patients with no therapeutic limitations who could all be admitted at any time to the ICU for mechanical ventilation in the event of clinical deterioration. The main explanation for not reaching statistical significance is a small sample size, probably related to the

TABLE 2 Primary and secondary outcomes

	Self-proning	Usual care	Difference between groups (95% CI)
Patients	10	17	
O_2 nasal flow L·min^{-1}			
At baseline	2.5 (2.0–3.0)	2.0 (1·0–3·0)	
At 24 h	1 (0.1–2.9)	2.0 (0.5–3.0)	−1 (−2.75–2)
S_{pO_2}/F_{iO_2} ratio			
At baseline	318 (284–341)	336 (303–388)	
At 24 h	390 (303–432)	336 (294–422)	54 (−91.6–133.0)
Respiratory rate breaths·min^{-1}			
At baseline	22.0 (20.0–25.8)	20.0 (16.0–26.0)	
At 24 h	20.0 (17.3–22.8)	20.0 (18–24.0)	0 (−6.5–3.5)
Heart rate beats·min^{-1}			
At baseline	83 (71–96)	82 (75–89)	
At 24 h	83 (72–89)	80 (70–86)	3 (−13–15)

Data are presented as n or median (interquartile range), unless otherwise stated. The difference between medians of the two randomised groups have been computed with their 95% confidence interval obtained by bootstrap using 1000 replications. O_2: oxygen; S_{pO_2}: peripheral oxygen saturation; F_{iO_2}: inspiratory oxygen fraction.

early interruption of study enrolment. Indeed, a very sharp decrease in COVID-19-related admissions was observed from mid-April 2020 as a result of effective containment measures in Switzerland. The results of this trial are promising, but adequately powered trials are still needed. Our data are in agreement with previous physiological studies and observational reports on prone positioning [11–16, 23].

Our study has some additional limitations. The intervention and assessments of end-points were limited to a 24-h time frame. Therefore, it is not possible to assess medium-term effects on outcomes and follow-up of self-prone positioning. Moreover, according to recent published reports on prone positioning, the effect on oxygenation is transient [14, 15]. As assessment at 24 h was performed in the supine position, the effect of the intervention on oxygen needs could have been minimised, although our data suggest that alternating supine and prone position over 24 h may be associated with lower oxygen needs at 24 h, even in the supine position. Finally, follow-up time in the medical ward was very short and the oxygen needs of patients with acute respiratory failure related to COVID-19 pneumonia should be closely monitored for >24 h, as rapid clinical deterioration is well described in a time window of 7–10 days after the onset of first symptoms [2, 24].

In summary, self-prone positioning in patients with COVID-19 pneumonia requiring low-flow oxygen therapy showed a reduction of oxygen needs in our study, which did not reach statistical significance, probably due to a small sample size and insufficient statistical power. However, the observed reduction of oxygen needs at 24 h is clinically promising without any reported major side-effects. Our findings need to be corroborated by larger randomised trials to confirm the potential beneficial effects of self-prone positioning on oxygen needs. This information would be of particular interest for healthcare systems in low-income countries with a limited access to ICUs.

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This study is registered at https://www.kofam.ch/en/snctp-portal/ with identifier number SNCTP000003718. The individual participant data that underlie the results reported can be shared. The study protocol and statistical analysis plan are also available. Data can be shared with researchers/investigators providing methodologically sound proposals.

Author contributions: A. Kharat and D. Adler designed the study. A. Kharat, C. Cantero, C. Marti, O. Grosgurin, S. Lolachi, F. Lador, J. Plojoux, J-P. Janssens and P.M. Soccal contributed to enrolment and data acquisition. E. Dupuis-Lozeron performed statistical analyses. A. Kharat and D. Adler drafted the first version of the manuscript. All authors assisted with data interpretation, manuscript preparation, and final manuscript review.

Conflict of interest: A. Kharat has nothing to disclose. E. Dupuis-Lozeron has nothing to disclose. C. Cantero has nothing to disclose. C. Marti has nothing to disclose. O. Grosgurin has nothing to disclose. S. Lolachi has nothing to disclose. F. Lador has nothing to disclose. J. Plojoux has nothing to disclose. J-P. Janssens has nothing to disclose. P.M. Soccal has nothing to disclose. D. Adler has nothing to disclose.

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BMC Research Notes

RESEARCH NOTE

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Prone positioning improves oxygenation and lung recruitment in patients with SARS-CoV-2 acute respiratory distress syndrome; a single centre cohort study of 20 consecutive patients

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Abstract

Objective: We aimed to characterize the effects of prone positioning on respiratory mechanics and oxygenation in invasively ventilated patients with SARS-CoV-2 ARDS.

Results: This was a prospective cohort study in the Intensive Care Unit (ICU) of a tertiary referral centre. We included 20 consecutive, invasively ventilated patients with laboratory confirmed SARS-CoV-2 related ARDS who underwent prone positioning in ICU as part of their management. The main outcome was the effect of prone positioning on gas exchange and respiratory mechanics. There was a median improvement in the PaO_2/FiO_2 ratio of 132 in the prone position compared to the supine position (IQR 67–228). We observed lower PaO_2/FiO_2 ratios in those with low (< median) baseline respiratory system static compliance, compared to those with higher (> median) static compliance ($P<0.05$). There was no significant difference in respiratory system static compliance with prone positioning. Prone positioning was effective in improving oxygenation in SARS-CoV-2 ARDS. Furthermore, poor respiratory system static compliance was common and was associated with disease severity. Improvements in oxygenation were partly due to lung recruitment. Prone positioning should be considered in patients with SARS-CoV-2 ARDS.

Keywords: Respiratory distress syndrome, Adult, Prone position, Severe acute respiratory syndrome coronavirus 2

Introduction

Acute Respiratory Distress Syndrome (ARDS) resulting from SARS-CoV-2 infection has a high mortality rate (>40%) [1]. It has been demonstrated that prone positioning reduces mortality in non COVID-19 ("classic") severe ARDS [2]. This may be due to optimized lung recruitment, reduced lung strain, and more homogeneous and therefore lung-protective ventilation in the prone position [3]. However, patients with COVID-19 pneumonia fulfilling the Berlin criteria for ARDS [4] may present with an atypical form of the syndrome [5–7]. In particular it has been suggested that the majority of patients with SARS-CoV-2 ARDS have relatively compliant lungs with low recruitability [5, 6]. This could imply

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that the response to prone positioning may differ in SARS-CoV-2 ARDS compared to "classic" ARDS. In particular, lung recruitment should not occur in the prone position in compliant lungs. This should result in (1) smaller improvements in oxygenation than seen in "classic" ARDS and (2) a reduction in total respiratory system compliance (because of the failure of lung recruitment to compensate for the reduction in chest wall compliance that is consistently seen in prone positioning [8]).

The response to prone positioning in SARS-CoV-2 ARDS has not been well described. We aimed to characterize this response. We hypothesized that poor compliance would be less common in SARS-CoV-2 ARDS than in "classic" ARDS and that prone positioning would result in small improvements in oxygenation with deterioration in overall respiratory system compliance, as a consequence of failure of lung recruitment.

Main text

Materials and methods

Study setting and design

Our study is a prospective cohort study of the first 20 patients with SARS-CoV-2 ARDS who underwent prone positioning in the intensive care unit (ICU) of our tertiary referral hospital. Included patients were admitted between the 16th March, 2020 and the 8th of April, 2020. Ethical approval was obtained from the local institutional review board. We included patients > 18 years of age who had laboratory confirmed SARS-CoV-2 infection, were invasively ventilated in the ICU, met the Berlin criteria for the diagnosis of ARDS [4] and underwent prone positioning as part of their management. Consent or assent was obtained as appropriate in accordance with the relevant local regulatory frameworks and national legislation. SARS-CoV-2 infection was confirmed using reverse transcriptase polymerase chain reaction testing on respiratory samples. All patients included were studied at the first session of prone positioning. Patients were identified from a prospective record of patients undergoing prone positioning in critical care areas. All patients included were ventilated in a mandatory volume control mode using ramped descending inspiratory flow and a lung-protective mechanical ventilation protocol. Institutional policy was that positive end-expiratory pressure (PEEP) should be set according to the ARDSNet PEEP tables [9]. Patients were excluded if they were younger than 18 years of age or, if due to surge demand exceeding capacity to maintain an electronic healthcare record (EHR) for all patients, they were cared for in areas where paper records were maintained and routine electronic data were not recorded. We also excluded patients who declined consent or where we could not obtain assent from the next of kin.

Data collection

Observations were obtained from analysis of routine clinical data in the EHR. We collected baseline data including demographic data and severity of illness data (PaO_2/FiO_2 (PF) ratio, SOFA score). For each patient we determined serial observations of ventilator parameters, measurements of respiratory mechanics and gas exchange before, during and after the first period of prone positioning. Plateau pressures were obtained at end expiration during zero-flow conditions.

ICU free days and ventilator free days (VFDs) were also determined from the EHR. 28-day mortality was also recorded. Ventilator free days were defined as days following intubation that the patient was alive and not mechanically ventilated for the 28-day period following their initial intubation. ICU free days were defined as any day not spent in a critical care area within the 28 days following their initial intubation.

Electrical impedance tomography (EIT)

We performed Electrical impedance tomography (EIT) in a further 3 patients with SARS-CoV-2 ARDS, using a clinical device as part of routine care (PulmoVista 500, Draeger Medical, Luebeck, Germany). Briefly, this non-invasive technique utilizes an electrode belt containing 16 electrodes, placed around the thorax in the fifth intercostal space, and one reference electrode placed on the abdomen. It's measurement principle has been described in detail elsewhere and involves the creation of two-dimensional transverse single-slice images based on changes in impedance distribution originating from ventilation [10]. EIT can be used to assess lung recruitment [11]. We compared regional impedance variations 1 h before and after each patient's first treatment with prone positioning.

Statistical analysis

Descriptive analyses were expressed as median (interquartile range [IQR]) for continuous variables and as percentages for categorical variables. Comparative statistics used repeated measures two-way analysis of variance (ANOVA) and Mann–Whitney U test as appropriate. For repeated measures two-way ANOVA we excluded patients where routine data were missing for relevant observations. All statistical analysis was performed using GraphPad version 8.0 (GraphPad Software, San Diego, USA).

Results

During the study period 21 patients underwent prone positioning in the ICU. In total, 20 patients met the inclusion criteria and were included in the analysis. A single patient was treated in an area without an electronic health record system and thus was excluded from the analysis. The baseline characteristics of the final cohort (n = 20) are summarized in Table 1.

The majority of patients were male, obese, with high severity of illness scores and had undergone a trial of either non-invasive ventilation or high flow nasal oxygen therapy prior to intubation. Most patients had moderate to severe ARDS by Berlin criteria. Low respiratory system static compliance (C_{RS}) was common prior to prone positioning. All patients received low tidal volume ventilation (tidal volumes < 8 ml/kg predicted body weight) and the majority of patients spent at least 16 h in the prone position.

The trend in PaO_2/FiO_2 ratios in the cohort before, during and after prone positioning is illustrated in Fig. 1a. There was a median improvement in the PaO_2/FiO_2 ratio of 132 in the prone position compared to the supine position (IQR, 67–228).The majority (90%) of patients experienced an increase in PaO_2/FiO_2 ratio of > 20% of baseline. Similarly, there was a significant and sustained decrease in Alveolar–arterial (Aa) oxygen gradient observed over the duration of prone positioning (Fig. 1b). The median decrease in Aa gradient was 212 mmHg (IQR, 134–359). There was no significant difference in C_{RS} noted throughout prone positioning (Fig. 1c). Patients with low (< median) C_{RS} had significantly lower baseline PF ratios when compared to those with higher (> median) C_{RS} ($P < 0.05$) (Fig. 1d).

The supine and prone comparisons of EIT measures of ventilation are presented in Fig. 2. Two out of three of the patients had evidence of early recruitment (increase in tidal impedance variation) in dorsal lung regions in the prone position compared to the supine position.

The majority of patients (85%) underwent further periods of prone positioning. A 28-day mortality rate of 15% was observed and the median number of ventilator free days among the cohort at 28 days was 16 (IQR, 0–21). The median number of ICU free days at 28 days in the cohort was 14.5 (IQR, 0–20).

Discussion

In this prospective cohort study of invasively ventilated SARS-CoV-2 ARDS patients, we identified a marked and sustained improvement in measures of oxygenation in consecutive patients undergoing prone positioning. This improvement in gas exchange with prone positioning was not associated with a change in respiratory system static compliance.

We do not believe that our observations are consistent with SARS-CoV-2 ARDS representing an entity distinct from "classic" ARDS. Firstly, the vast majority (90%)

Table 1 Patient Characteristics, Blood Gas and Ventilatory Variables

Patient characteristics	Median (IQR)	
Age (years)	54.0 (45.0–59.5)	
Male (%)	90%	
BMI (kg/m^2)	36.0 (30.0–43.4)	
SOFA score	8.0 (6.0–10.7)	
Duration between onset of symptoms and admission to ICU (days)	10.5 (7.2–15.0)	
Respiratory support prior to admission (NIV/HFNC), No. (%)	12 (60%) / 2 (10%)	
Duration of first prone positioning session, hours	16.2 h (15.6–17.4)	
Length of ICU stay prior to prone positioning	1 day (1–1.75)	
Arterial blood gas variables	Pre-prone positioning	During prone positioning
pH	7.30 (7.23–7.35	7.30 (7.22–7.36)
PaO_2 (kPa)	12.5 (10.1–13.2)	14.3 (12.7–20.4)
$PaCO_2$ (kPa)	7.0 (6.1–8.0)	7.3 (6.6–8.5)
Ventilatory variables		
Plateau airway pressure (cmH_2O)	26 (20–28)	26 (22–29)
Tidal volume (mL)	426 (391–461)	436 (393–470)
PEEP (cmH_2O)	14 (10–16)	14 (10–15)
FiO_2 (%)	70 (60–95)	45 (36–55)
PaO2/FiO2 (mmHg)	123 (100–154)	286 (195–348)
Aa Gradient (mmHg)	342 (275–507)	114 (64–207)
C_{RS} (ml/cmH2O)	33.7 (30.1–43.0)	32.5 (26.7–37.5)

BMI body mass index, *SOFA* sequential organ failure assessment, *NIV* non-invasive ventilation, *HFNO* high flow nasal oxygen, *PaO_2* arterial partial pressure of oxygen, *$PaCO_2$* arterial partial pressure of carbon dioxide, *PEEP* positive end-expiratory pressure, *FiO_2* fraction of inspired oxygen, *Aa* alveolar-arterial, *C_{RS}* static compliance

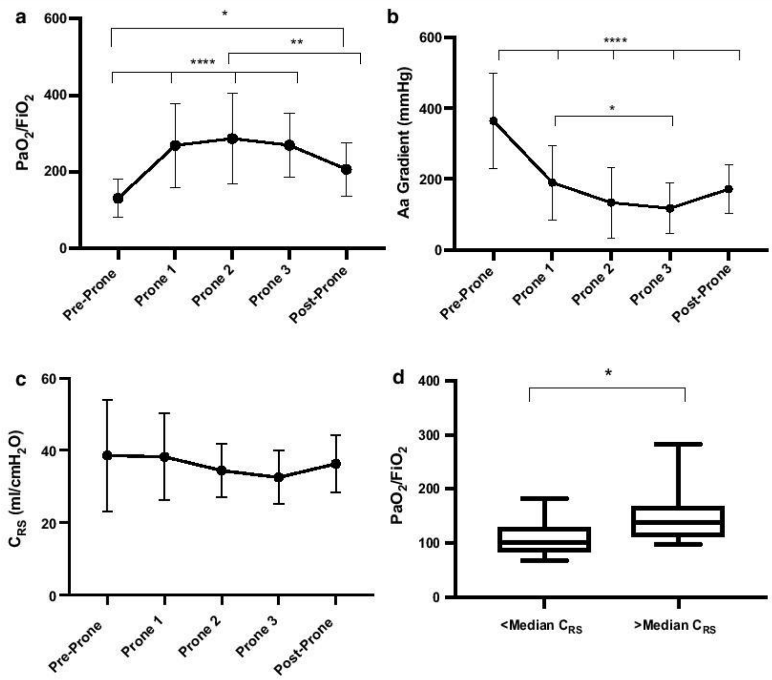

Fig. 1 The effect of prone positioning on gas exchange and respiratory mechanics are shown in (**a–c**). **a** Line graph representing mean PaO2/FiO2 ratio before, during, and after prone positioning, n=20, **b** Line graph representing mean Aa gradient before, during, and after prone positioning, n = 20, (**c**) Line graph representing mean respiratory system static compliance (CRS) before, during, and after prone positioning, n = 15, (**d**) shows the association between respiratory system static compliance (CRS) and severity of SARS-CoV-2 ARDS. It displays a box plot representing the difference in baseline PF ratio between patients with <median CRS and > median CRS, n = 19. PF = PaO2/FiO2 ratio, Aa = Alveolar-arterial gradient, CRS = respiratory system static compliance. Pre-Prone = immediately prior to prone positioning, Prone 1 = following prone positioning, Prone 2 = the mid-point of prone positioning, Prone 3 = prior to supination, and Post-Prone = following supination. Statistical Analysis: Analyzed by repeated measures two-way ANOVA with Tukey's post-hoc test for multiple comparisons for line graphs and Mann-Whitney U test for box plot. ****P<0.0001, ** P<0.01, * P<0.05. Patients with incomplete data sets were excluded from analysis. **a–c**: error bars represent standard deviation. **d**: box plot with bars representing range.

of patients experienced an increase in PF ratio > 20% of baseline, which is consistent with previous observations in "classic ARDS" [12]. While the magnitude of this effect might appear greater than previously observed in "classic" ARDS [13–17], this is likely due to our early prone positioning strategy, which has previously been shown to be associated with improved oxygenation response [13]. Indeed a recent report of very early prone positioning in SARS-CoV-2 ARDS also observed an increased magnitude of effect [18].

Secondly, poor compliance was implicated in disease severity, and there was evidence of lung recruitability, both of which are characteristics of "classic" ARDS. In the first instance there was a strong association between more severe SARS-CoV-2 ARDS and poorer static compliance in our cohort. Patients with lower static compliance had lower baseline PF ratios. Absolute levels of compliance were low and comparable with previous studies in "classic" ARDS [19, 20]. Also, we did not observe a reduction in static compliance during prone positioning, as would be expected if lung recruitment did not occur. As we know that chest wall compliance consistently falls during prone positioning [8], this must mean that lung compliance improved (because total respiratory compliance is the sum of chest wall compliance and lung compliance). This appears most likely to be due to

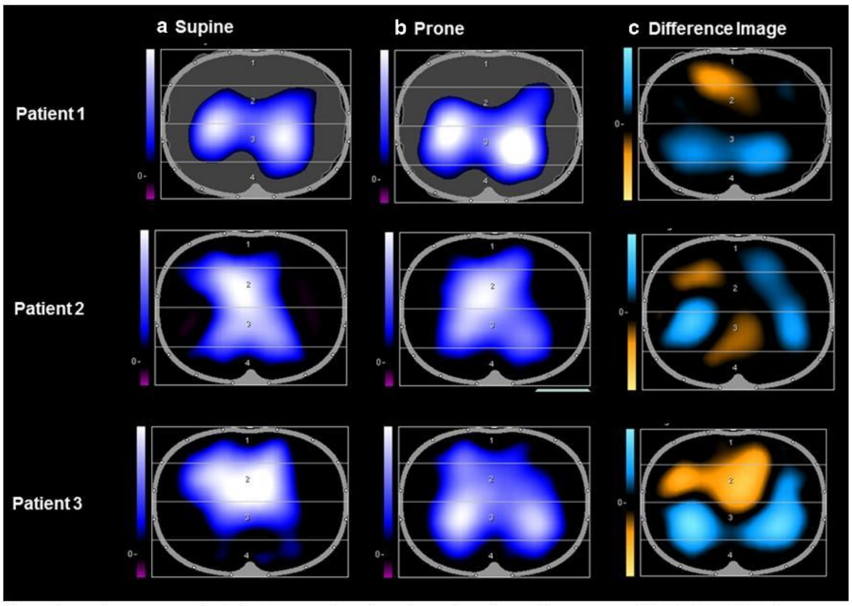

Fig. 2 Electrical impedance tomographs (PulmoVista 500, Dräger) are shown above for 3 adult patients with SARS-CoV-2 ARDS who were invasively ventilated and underwent prone positioning. **a** represents the end-inspiratory trend view prior to prone positioning. **b** represents the end-inspiratory trend view following prone positioning. In (**a, b**), areas of increasing impedance variation (corresponding to greater ventilation) are represented in order of increasing variation in black (none), blue (intermediate) and white (greatest) colors. **c** represents the difference between the images in **a, b**, displaying loss of regional ventilation (areas in orange) which represent ventral regions being over-distended in the supine position and gain of regional ventilation (areas in blue) which represent recruitment of the dorsal regions upon prone positioning. Patients 1 and 3 showed an increase in tidal impedance variation in dorsal regions in the prone position and a decrease in tidal impedance variation in the ventral regions, which is consistent with lung recruitment dorsally.

recruitment of poorly compliant lung in the prone position, as occurs in "classic" ARDS. While total compliance did not improve, this is actually a very common finding in prone positioning in "classic" ARDS [8]. Moreover, serial electrical impedance tomography (EIT) measurements in a small convenience sample demonstrated recruitment of dorsal lung regions in the prone position in two of three patients.

Our observations may conflict with previous data indicating that the majority of patients with SARS-CoV-2 ARDS have relatively normal lung compliance [5, 21] but agree with a more recent dataset [18]. The response to prone positioning in our cohort seems typical of "classic" ARDS. It could be argued that this provides grounds to generalise the findings of improved mortality with prone positioning in "classic" ARDS to patients with SARS-CoV-2 ARDS. However, randomized controlled trials would be needed to definitively confirm this.

Conclusion

Prone positioning was effective in improving oxygenation in SARS-CoV-2 ARDS. Furthermore, poor respiratory system static compliance was common and improvements in oxygenation were partly due to recruitment of poorly compliant lung. Prone positioning should be considered in patients with SARS-CoV-2 ARDS.

Limitations

Our study had several limitations. Firstly, the small convenience sample and the single-centre, observational nature of the study may limit generalisability. We used routine data and our conclusions about lung compliance are based on inferences based on total respiratory system compliance rather than direct measurements of lung compliance. Additionally, while selection bias could have influenced patient characteristics observed, we do not believe that this is a significant issue as the vast majority

(73%) of COVID-19 ARDS patients admitted to our ICU during the study period underwent prone positioning.

Abbreviations

ARDS: Acute respiratory distress syndrome; COVID-19: The disease caused by SARS CoV-2 infection; C_{RS}: Total respiratory system static compliance; EHR: Electronic health record; EIT: Electrical impedance tomography; ICU: Intensive care unit; PEEP: Positive end expiratory pressure; PF Ratio: PaO2/FiO2 ratio; SARS CoV-2: Severe acute respiratory syndrome coronavirus-2; SOFA: Sequential organ failure assessment; VFD: Ventilator free days.

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Not applicable.

Authors' contributions

Authors GC, GMcE, JL, BMcN, JC, NMcE and PG contributed to the conception and design of the study. Authors JC, NMcE, MB, ONiC, MM, AK, GH, OMcE1, OMcE2 and JB collected data. JC, PG, NMcE and GC analysed the data. JC, PG, GC, GMcE, JL and BMcN prepared drafts of the manuscript and substantively revised it. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to relevant data protection laws but may be available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Ethical approval was obtained from the Beaumont Hospital Ethics Committee (Reference #1706). Consent or assent was obtained for all participants as appropriate and in accordance with local regulatory frameworks and national legislation. In the first instance we tried to obtain written consent from the patient. If this was not possible we obtained written family member assent face-to-face. If this was also not possible we obtained telephone assent from family members. When patients regained capacity, written consent was obtained. This procedure was approved by the local ethics committee in light of Covid-19 restrictions.

Consent for publication

Not applicable.

Competing interests

The authors declare they have no competing interests.

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LETTER TO THE EDITOR

Effects of prone and lateral position in non-intubated patients with 2019 Novel Coronavirus (COVID-19) pneumonia

To the Editor:

Mechanical ventilation in the prone position is a validated strategy of invasive ventilator support in the treatment of acute respiratory distress syndrome (ARDS).[1] Given its beneficial effects, there has been some research into the use of prone positioning also in non-intubated patients with ARDS[2,3] and in patients with COVID-19 to avoid intubation,[4,5] but few studies[2,3,6,7] have assessed its efficacy and possible effects during SARS Cov-2 pandemic.[8–13] The use of standard oxygen and High Flow Nasal Cannula (HFNC) in refractory hypoxemia due to SARS CoV-2 is controversial and many International Guidelines, while suggesting a brief trial, raise concerns about the potential risk of unduly delayed intubation. We describe the physiological changes and clinical outcome of three patients suffering from severe Acute Respiratory Failure (ARF) due to COVID-19 undergoing trials using semi-recumbent, prone and lateral position during standard oxygen and HFNC. All patients tested positive on reverse transcription-polymerase chain reaction (RT-PCR) on throat swabs; comorbidities and administered drugs are reported in Table 1.

A 74 year-old woman was admitted on March 19th, after 10 days of fever. On the 24th she was transferred to our Respiratory Intensive Care Unit (RICU) due to worsening of her respiratory conditions. On arrival, she was haemodynamically stable, her respiratory rate was 18/min in a reservoir oxygen mask at 15 l/min; ABG testing showed a severe impairment of gas exchange (PaO2/FiO2 87; PaO2 69 mmHg, PaCO2 33 mmHg, pH 7.49, HCO3- 27,8 mmol/L). We initiated non-invasive ventilation (NIV) with helmet interface (PSV: PS 22 cmH2O, PEEP 10 cmH2O, FiO2 80%), without improvement of gas exchange (PaO2/FiO2 80). A high resolution CT-scan (HRCT) showed bilateral consolidations with ground-glass opacities (GGO), mainly in the posterior dependent zones. Based on this radiological picture we pronated the patient whilst administering oxygen-therapy with reservoir mask. An almost immediate increase of SpO2 was observed (Fig. 1). At 2 h the PaO2/FiO2 had increased to 203 mmHg and this trend was maintained after 12 h of prone positioning (Table 1). She improved slowly with a schedule of pronation of two sessions lasting 6 h throughout the day and overnight and was discharged home on April 29th.

The second case was a 71-year-old man, admitted to the Emergency Department (ED) with fever and progressively worsening dry cough for one week. On admission, ABG showed ARF (PaO2/FiO2 261, PaO2 55 mmHg, PaCO2 31 mmHg, pH 7.45, HCO3-24 mmol/l). Clinical conditions and gas exchange rapidly worsened (ABG 48 h after admission: PaO2/FiO2 186, PaO2 65 mmHg, PaCO2 33 mmHg, pH 7.43, HCO3- 25,6 mmol/L) and on day 6 since admission he was referred to our RICU, where HFNC therapy was set (Flow 50 L/min, FiO2 50%). The HRCT scan showed parenchymal involvement of the left lung, with relative sparing of the right one. A spontaneous breathing trial was performed placing the patient on the right lateral decubitus during HFNC therapy. Respiratory rate rapidly decreased (from 22 to 16 breaths/min) and ABG showed a significant improvement of oxygenation (P/F ratio of 202 and 211 after 2 and 12 h respectively) (Table 1). Therefore, we scheduled at least two sessions lasting 6 h of lateral position throughout the day and overnight. He was transferred to the ward 8 days after ICU admission and discharged at home after 28 days.

The last patient was admitted to the ED after 6 days of fever, asthenia and dyspnoea. On admission, ABG was normal, but lung ultrasound documented signs suggestive of interstitial-alveolar pneumonia and a HRCT confirmed bilateral GGO associated with initial peripheral consolidations. The patient's condition deteriorated and she was transferred to our RICU, where HFNC therapy was started (Flow 45 L/min, FiO2 60%). A novel CT scan showed a relative sparing of the left lung, therefore she was placed in left lateral decubitus. Changes in oxygenation as well as in respiratory pattern are summarized in Table 1. Two sessions lasting 6 h of lateral position throughout the day and overnight determined a stable improvement of gas exchange and prevented mechanical ventilation. She was discharged home after 21 days from hospital admission.

Our findings indicate that this strategy is feasible and a useful option in the management of acute respiratory failure due to this disease. In fact, patient recumbency in accordance with imaging to adjust V/Q was associated with a significant improvement of oxygenation and breathing pattern, with good tolerance. In addition, we found no significant hemodynamic adverse effects. The physiologic rationale for prone positioning and lateral decubitus in non-intubated patients is strong: firstly, redistribution

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Table 1 Demographic, clinical characteristics, laboratory and CT-scan findings at respiratory intensive care unit admission, drugs, ABGs.

	Patient 1	Patient 2	Patient 3
Demographics			
Age-yr	74	71	70
Sex	Female	Male	Female
Initial findings			
Medical history	Dyslipidemia, hypothyroidism, carotid atheroma	Hypertension, deep venous thrombosis	Hypercholesterolemia and hypertension
Symptoms at disease onset	Fever	Fever, cough	Fever, asthenia, dyspnoea
Pharmacological treatment			
(dosages are shown for drugs initiated during RICU stay)	Hydroxychloroquine, piperacillin-tazobactam, azithromycin, enoxaparin, tocilizumab 162 mg x2 s.c., methylprednisolone 1,6 mg/kg	Hydroxychloroquine, enoxaparin, ceftriaxone, tocilizumab 162 mg x2 s.c., methylprednisolone 1 mg/kg	Hydroxychloroquine, azithromycin, enoxaparin, ceftriaxone, tocilizumab, methylprednisolone
Imaging features			
Thoracic HRCT scan	GGO, bilateral pulmonary infiltrates, mainly in the posterior dependent zones	GGO and consolidations prevalent on the left lug	GGO and pulmonary infiltrates prevalent on the right lung
Days from Hospital admission to prone/lateral decubitus	6	11	8

[10pt]

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Table 1 (*Continued*)

ABGs	Patient 1			Patient 2			Patient 3		
	PRE	During NIV	PP/LD after 12h	PRE	During HFNC	During PP/LD	PRE	During HFNC	During PP/LD
pH	7,49	7,48	7,47	7,42	7,45	7,43	7.48	7,49	7,45
PaCO2 (mmHg)	32	31	35	42	39	40	33	30	35
PaO2 (mmHg)	66	62	162	80	76	80	62	70	109
PaO2/FiO2	83	80	203	160	158	211	115	116	205
HCO_3- (mmol/L)	26	26	27	27	27	26	26	26	25
Vital Parameters									
	PRE	PP/LD after 2h	After 12h	PRE	PP/LD after 2h	After 12h	PRE	PP/LD after 2h	After 12h
RR (breaths per minute)	25	20	26	22	16	18	21	22	20
Heart rate (bpm)	87	72	80	74	60	65	68	64	65
Mean Arterial Pressure (mmHg)	97	113	107	108	97	103	88	87	96

RICU, Respiratory Intensive Care Unit; GGO, ground-glass opacities; s.c., sub cutaneous; NIV, non invasive mechanical ventilation; HFNC, High Flow Nasal Cannula; PP, prone position; LD, lateral decubitus.

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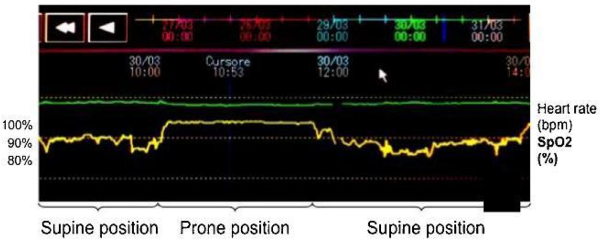

Figure 1 Pulse oximetry pleth waveform of the same patient during supine and prone position.

of V/Q ratio due to the gravity-induced increase of blood flow to spared regions of the lung, which becom better ventilated[14]; secondly, lung recruitment of previously dependent regions occurs as ''oedema'' flows away from anti gravitational alveoli.[14] Similarly, positioning patients with unilateral pleuro-parenchimal disease with the normal lung down, especially in the absence of pleural pain, can affect gas exchange.[15,16] Thirdly, the increase in oxygenation should also ameliorate hypoxemic vasoconstriction, reducing pulmonary vascular resistance and improving right ventricular function.[17] In addition, in the prone position we may obtain a relief from the weight of the mediastinum and a decrease in overdistension of the healthy areas, thanks to the distribution of trans-pulmonary pressure. In fact, recruitment of the dorsal lung, which has a higher degree of perfusion in either position, reduces shunt.[18,19] A retrospective study including 15 patients showed a beneficial effect of prone position during NIV in patients with severe ARF due to pneumonia.[2] Recently, Ding[3] reported a reduction in intubation rate in patients with moderate to severe ARDS when treated with combined prone positioning and NIV or HFNC.

Recent studies[8–13] showed that prone positioning may improve gas exchange in COVID-19 patients during oxygen therapy and non invasive support (HFNC or NIV). However, no information about the radiological pattern has been provided. In contrast, our cases showed that the distribution of parenchymal lesions could be a valid criterion to select patient for spontaneously breathing trial in prone positioning and lateral decubitus. Chest x-ray could be useful to support diagnosis, especially during Sars-cov 2 pandemic: sensitivity values range from 57% to 89%.[20] However, Chest-x-ray can not detect spared lung areas: exclusive dorsal lung areas involvement can not be detected without latero-lateral projection, not usually performed in critical setting, requiring orthostatic posture. As observed by Marini,[4] COVID-19 pneumonia appears to include an important vascular insult that potentially mandates a different approach from that usually applied for ARDS. Our patients, despite very poor oxygenation and extensive parenchymal lesions, recovered without needing either NIV or intubation, and such a result would not, probably, have been possible in a ''traditional'' ARDS. All healthcare workers exposed used personal protective equipment (PPE).[21] Interestingly, in all 3 cases reported we observed that $PaCO_2$ did not change, indicating that the change in PaO_2 was not a consequence of a change in alveolar ventilation, supporting the theory of a beneficial effect on V/Q ratio. However, we do not recommend delaying intubation or attempting this approach in a setting without intensive monitoring, which is necessary to quickly upgrade ventilatory support in non-responders.

To conclude, we have demonstrated that preferential decubitus on the least affected areas of the lung, either in prone or lateral position, in awake and spontaneously breathing, non-intubated patients with ARF due to COVID-19 pneumonia is feasible, well tolerated and is associated with a significant benefit on oxygenation. Further studies are warranted to confirm our results.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Rapid implementation of a mobile prone team during the COVID-19 pandemic

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A R T I C L E I N F O

Keywords:
Coronavirus disease 2019 (COVID-19)
Acute respiratory distress syndrome (ARDS)
Prone positioning

A B S T R A C T

Purpose: The coronavirus disease 2019 (COVID-19) is associated with high rates of acute respiratory distress syndrome (ARDS). Prone positioning improves mortality in moderate-to-severe ARDS. Strategies to increase prone positioning under crisis conditions are needed.
Material and methods: We describe the development of a mobile prone team during the height of the crisis in New York City and describe characteristics and outcomes of mechanically ventilated patients who received prone positioning between April 2, 2020 and April 30, 2020.
Results: Ninety patients underwent prone positioning for moderate-to-severe ARDS. Sixty-six patients (73.3%) were men, with a median age of 64 years (IQR 53–71), and the median PaO_2:FiO_2 ratio was 107 (IQR 85–140) prior to prone positioning. Patients required an average of 3 ± 2.2 prone sessions and the median time of each prone session was 19 h (IQR 17.5–20.75). By the end of the study period, proning was discontinued in sixty-seven (65.1%) cases due to clinical improvement, twenty (19.4%) cases due to lack of clinical improvement, six (5.8%) cases for clinical worsening, and ten (9.7%) cases due to a contraindication.
Conclusion: The rapid development of a mobile prone team safely provided prone positioning to a large number of COVID-19 patients with moderate-to-severe ARDS.

1. Introduction

During the coronavirus disease 2019 (COVID-19) pandemic, an overwhelming majority of those requiring ICU level of care had acute hypoxemic respiratory failure requiring mechanical ventilation for acute respiratory distress syndrome (ARDS) [1]. ARDS is common. In one large observational study, 23.4% of patients requiring mechanical ventilation for acute respiratory failure met criteria for ARDS. Mortality from ARDS depends on severity, and ranges from 35 to 46% [2]. Prone positioning, when used in conjunction with low tidal volume ventilation, has been shown to significantly reduce mortality in moderate-to-severe ARDS [3-5]. Despite the evidence, the use of prone positioning in moderate-to-severe ARDS remains low [2,6]. Barriers to implementation of prone positioning include lack of provider recognition of ARDS, uncertainty of evidence, and resource utilization [2,3].

Our medical intensive care unit (MICU) instituted a prone positioning program in 2014 for the management of moderate-to-severe ARDS. The MICU Prone Program was a nursing-led initiative that trained MICU nurses in safe manual placement of patients with ARDS in the prone position. Indications for proning were based on prior evidence [4], including patients with moderate-to-severe ARDS with a ratio of partial pressure of arterial oxygen to fraction of inspired oxygen (PaO_2:FiO_2) of <150 despite standard-of-care management with low-volume, low-pressure ventilation and adequate ventilator synchrony. Between 2014 and 2019, our MICU successfully proned seventy-nine patients, with increasing experience over time.

New York City was an epicenter of the coronavirus disease 2019 (COVID-19) pandemic. In the face of this pandemic, our hospital increased our ICU capacity by over 250% in the setting of a surge of critically ill COVID-19 patients with acute respiratory failure. ICUs were created throughout the hospital in non-traditional areas including operating rooms, medical-surgical floors, post-procedural observation units

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and in the emergency department. Additionally, other subspecialty ICUs, including neurologic, pediatric, post-surgical and cardiac were repurposed to treat primarily adult patients with COVID-19-associated acute respiratory failure and ARDS requiring mechanical ventilation. Many of these patients met criteria for moderate-to-severe ARDS, but ICU staff outside of the MICU were not familiar with prone positioning. In an effort to increase our ability to meet this demand, we rapidly developed and trained a mobile prone team, capable of servicing ICUs throughout the hospital. Here we describe the series of patients with moderate-to-severe ARDS treated during the COVID-19 pandemic with prone positioning.

2. Methods

2.1. Prone team development

The COVID-19 Prone Team at NewYork-Presbyterian – Columbia University Irving Medical Center was developed as a dedicated mobile team comprised of a MICU clinical nurse specialist (CNS), occupational therapists (OTs), and physical therapists (PTs), who were redeployed to this role from their usual clinical jobs. Twelve OTs and twelve PTs were trained to be part of the team during the height of the pandemic. They all had cardiopulmonary rehabilitation experience, and most have worked with ICU patients as part of our early mobilization program. In addition to knowledge of body mechanics and positioning critically ill patients, they had experience in securing airways, lines, drains, and monitoring devices in an ICU setting.

These therapists underwent prone positioning training, developed by the MICU CNS, based on education materials that had been previously developed for the MICU Prone Program.

The MICU CNS led the development of the MICU Prone Program and had developed its protocol and nursing policy. In addition, the MICU CNS was certified in wound, continence and ostomy (CWOCN) with experience in pressure injury prevention and treatment. Training included education in basic principles of ARDS management and indications for prone positioning. It involved review of an instructional video [4], repetitive demonstration of equipment usage and positioning techniques, communication exercises to enhance overall teamwork during positioning, and proper donning and doffing of personal protective equipment (PPE).

To simulate a typical patient, a manikin equipped with an endotracheal tube, central venous catheter, arterial line, chest tube, foley catheter, cardiac monitor leads and a pulse oximeter lead was used for practice of positioning technique. The team performed multiple iterations of placement in prone and supine positions (Supplemental Image S1), including emergent positioning. Roles for team members included: team leader, airway manager (AM), turn team, line manager, recorder and vital signs monitor. Outside of the simulation environment, the role of AM was filled by a member of the ICU treating team or respiratory therapy. Training emphasized safety checks during positions to avoid loss of the airway, chest tubes, the central venous line or the arterial line. To avoid staff injury the training emphasized the importance of team members moving in sync.

Patients were manually positioned with the Tortoise Turning and Positioning System Prone (Mölnlycke Health Care, Gothenburg, Sweden) consisting of two low-pressure air-filled pads and two fluidized positioners to support and offload the patient. When this system was not available sheets were used to aid in the procedure. Due to the rapidly growing need for prone positioning beyond the MICUs, this training was completed in only two days prior to team launch.

The COVID-19 Prone Team covered 14 separate ICUs, a combined total of 240 COVID ICU beds. Their day-to-day availability increased based on demand, up to 7 days a week, from 7 am to 7 pm at the peak, for 22 days. If a patient needed to be emergently repositioned outside of the COVID-19 Prone Team hours, they were repositioned by MICU nurses. In the event of cardiac arrest, if a patient could not be safely placed in the supine position, the protocol specified the prone position should be maintained for cardiopulmonary resuscitation in an effort to minimize risk of ventilator circuit disconnect with the associated risk of aerosolization of viral particles [7,8]. To date during this pandemic, our institution has not had a patient in cardiac arrest while in the prone position.

The daily COVID-19 Prone Team included the MICU CNS and five to six OTs and PTs. During proning, the MICU CNS and four therapists would enter the patient's room, and the remaining therapists acted as a scribe and runner and remained outside of the room. A note was placed in the electronic medical record indicating time, safety checklist, positioning of patient, and PaO_2:FiO_2 ratio prior to repositioning. A member of the primary ICU treating team was required to be present during repositioning to manage emergencies. All patients who were proned were deeply sedated and receiving neuromuscular blockade during their proning session and during repositioning as previously described [4,9], and in an effort to minimize risk of virus exposure to the COVID-19 Prone Team via ventilator circuit disconnect or coughing by the patient [10].

2.2. Indications for proning

Patients who met criteria for prone positioning by the mobile prone team included those who were invasively mechanically ventilated with ARDS and a PaO_2:FiO_2 < 150 despite standard-of-care management with low-volume, low-pressure ventilation and adequate ventilator synchrony, and required an $FiO_2 \geq 60\%$ with positive end-expiratory pressure (PEEP) ≥10; the same indications established prior to the COVID-19 pandemic. Contraindications included clinical or physical conditions that precluded safe prone positioning (Table 3). Patients remained prone for 16–24 h per session. This length of time depended on the COVID-19 Prone Team availability. Proning was continued if the PaO_2:FiO_2 remained <150 when supine with $FiO_2 \geq 60\%$ and PEEP ≥10. Proning was discontinued when the PaO_2:FiO_2 was ≥150 with $FiO_2 \leq 60\%$ and PEEP ≤10 while supine, if a patient did not tolerate positioning as determined by the treating team, or if the treating team declined.

2.3. Data collection and analysis

Baseline characteristics and clinical measures, including sex, age, height, weight, date of endotracheal intubation, date of prone position initiation, mechanical ventilator settings and Sequential Organ Failure Assessment (SOFA) score at time of prone position initiation were retrospectively collected for all patients treated by the COVID-19 Prone Team from April 2 through April 30, 2020. Further clinical measures and patient outcomes, including number of daily positionings completed, duration of proning, PaO_2:FiO_2 during proning, adverse events during proning, patient tolerance of prone positioning, days on mechanical ventilation, tracheostomy, and mortality were collected through May 14, 2020. Continuous variables were expressed as means (+/− Standard Deviation) and medians (Interquartile range). Categorical variables were summarized as counts and percentages. This study was approved by Columbia University Irving Medical Center Institutional Review Board (study number AAAT0603).

3. Results

Between April 2 and April 30, 2020, ninety patients were treated by the COVID-19 Prone Team. Of these ninety patients, thirteen required two unique proning episodes at separate time points during their hospitalization due to recurrent moderate-to-severe ARDS that met criteria for prone positioning. All patients requiring proning during this time were proned by this team, including within the MICUs. During this

Table 1
Baseline characteristics.

Study Population	N = 90
Age, median (IQR)	64 (53–71)
Sex, n (%)	
Female	24 (26.7)
Male	66 (73.3)
Height, inches, mean ± SD	66.1 ± 3.62
BMI, median (IQR)	29.4 (26.1–33.9)
Comorbidities, n (%)	
Hypertension	50 (55.6)
Diabetes mellitus	42 (46.7)
SOFA score on day of first prone session, mean ± SD	10.3 ± 2.5
ICU location, n (%)	
Medical	15 (16.7)
Neurologic	12 (13.3)
Cardiac	13 (14.4)
Surgical	10 (11.1)
Operating Room	16 (17.8)
Medical/Surgical Floor Converted	9 (10)
Pediatric	6 (6.7)
Cardiothoracic	7 (7.8)
Post-procedural observation units	1 (1.1)
Emergency Department	1 (1.1)
Tidal Volume at time of first prone session, cc/kg of predicted body weight, median (IQR)	6.0 (5.5–6.26)
Median plateau pressure at time of first prone session, cm H_20, median (IQR)	30 (28–34)
PEEP prior to prone session, mean ± SD	14 ± 3.96
FiO_2 prior to prone sessions, median (IQR)	0.8 (0.7–1.0)
PaO_2:FiO_2 prior to prone sessions, median (IQR)	107 (85–140)
Time from intubation to first prone session, days, median (IQR)	6 (IQR 2–11)

BMI = body mass index; SOFA = sequential organ failure assessment; ICU = intensive care unit; cc/kg = centimeters per kilogram; cm H_20 = centimeters of water; PEEP = positive end expiratory pressure; FiO_2 = fraction of inspired oxygen; PaO_2 = partial pressure or arterial oxygen.

same period, 314 patients were admitted to our hospital with COVID-19 requiring invasive mechanical ventilation. Baseline characteristics of these patients are shown in Table 1. The majority of patients who required prone positioning were men (73.3%), with a median age of 64 years (range 53–71). There was a high prevalence of comorbid hypertension (55.6%) and diabetes (46.7%). All of the ICUs, including those newly created during the COVID-19 pandemic, had patients treated by the COVID-19 Prone Team.

The median time between intubation and first prone session was 6 days (IQR 2–11). A total of 244 individual prone positionings were performed by the COVID-19 Prone Team during the study period. Patients were maintained in the prone position for a median of 19 h (IQR 17.5–20.75) per session. Patients required an average of 3 ± 2.2 sessions. The COVID-19 Prone Team completed an average of 15.3 ± 4.5 positionings per daily shift (Fig. 1).

By the end of the study period, proning was discontinued in sixty-seven (65.1%) cases due to improvement in gas exchange, in twenty (19.4%) cases due to lack of clinical improvement, in six (5.8%) cases for clinical worsening and in ten (9.7%) cases due to the development of a contraindication. Thirty-six patients died and 54 remained alive (Table 2). Recorded adverse events during prone sessions included peripheral intravenous line dislodgement in one patient, severe periorbital edema in one patient, brachial plexus injury in one patient, facial pressure injury in one patient, pressure injury to the ear in two patients and hypotension and hypoxemia in five patients requiring placement back into the supine position. No patients had a cardiac arrest while in the prone position.

4. Discussion

The rapid implementation of the mobile COVID-19 Prone Team that travelled to multiple ICUs at our institution during the height of the COVID-19 pandemic, increased the ability to prone patients with moderate-to-severe ARDS. In a 28-day period, 90 patients were proned by this team with 244 individual proning sessions. After implementation of the COVID-19 Prone Team, more patients who met criteria for prone positioning were actually proned, as 12 patients intubated were proned between March 2, 2020 and March 31, 2020 [1] compared to 90 during the study period. By utilizing OTs and PTs who were familiar with critical illness and positioning patients, and by developing a careful but efficient training program, the COVID-19 Prone Team was able to safely provide an evidence-based intervention to critically ill patients with ARDS in a variety of ICU settings.

Prone positioning has been shown to have a mortality benefit in patients with moderate-to-severe ARDS, but has been underutilized due to provider under-recognition of ARDS, frequent misunderstanding of its indications, disbelief in quality of evidence, and resource utilization [11], which during times of crisis is more pronounced [2,12]. During the COVID-19 pandemic, the concentration of patients with moderate-to-severe ARDS increased considerably. This increase required rapid

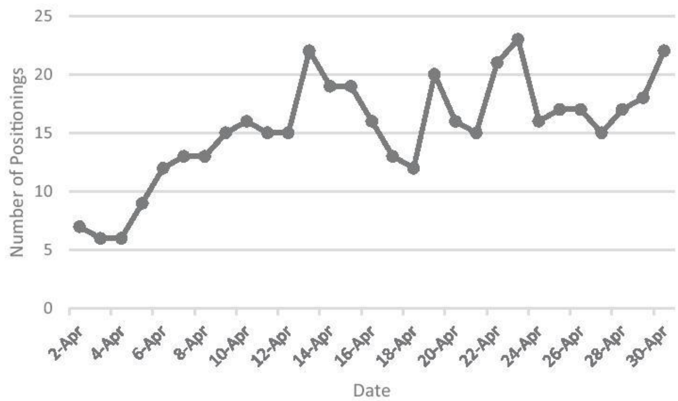

Fig. 1. Number of interventions per day: Daily number of interventions completed by the prone team. Includes placing in both the supine and prone position. X axis represents dates in April 2020.

Table 2
Outcomes.

Reason for Discontinuing Proning, n(%)[a]	N = 103 prone episodes
Improvement in gas exchange	67 (65.1)
Lack of clinical improvement	20 (19.4)
Clinical worsening	6 (5.8)
Developed a contraindication	10 (9.7)
Outcome at end of study period, n(%)	N = 90 unique patients
Dead	36 (40)
Alive	54 (60)
Extubated	11 (20.4)
Remains orally intubated at end of study period	17 (31.5)
Underwent Tracheostomy	26 (48.1))

[a] Thirteen patients required 2 unique proning episodes at separate time periods due to recurrent episodes of moderate-to-severe ARDS.

expansion of educational efforts on ARDS management. Additionally, as part of a clinical staffing strategy, critical care trained physicians provided clinical oversight across all ICU beds, allowing for relative consistency in the management of these patients with ARDS, as evidenced by the consistent use of a low tidal volume ventilation strategy, and identification of patients who met criteria for prone positioning. From a resource perspective, the staffing of a COVID-19 Prone Team with OTs and PTs available for redeployment during the crisis avoided additional strain on clinical nursing and other bedside clinicians who were already understaffed during this time. The ability to focus the training on a small group of individuals dedicated to proning appeared to enhance efficiency, expertise and safety.

This study has several limitations. While we are able to describe the characteristics of the patients treated, we have limited data to define the overall population of moderate-to-severe ARDS patients in our hospital during the study period. It is unclear what proportion of patients with moderate-to-severe ARDS received this therapy when indicated. Also, with limited data on the incidence of moderate-severe ARDS in our hospital prior to the COVID-19 pandemic, it is unclear if our proning rate changed with this implementation. However, prior to COVID-19, proning was only available to patients in the MICUs therefore limiting this treatment to the capacity of the MICU. Lastly, our outcomes data is limited by the study duration. At the end of the study, forty-five patients were still hospitalized, therefore the outcome of these treated patients is yet to be determined. However, of the fifty-four patients whose hospital survival is yet to be determined, thirty-six (80%) patients had prone therapy stopped due to clinical improvement.

Table 3
Potential contraindications to prone positioning.

Significant hemodynamic instability
Severe acidemia
Cerebral perfusion pressure < 30 mmHg
Increased ICP >30
Pregnancy
History of difficult intubation or nasotracheal intubation
DVT treated for <2 days
Facial surgery or severe facial trauma
Massive hemoptysis
Pelvic fractures
Active intra-abdominal process
LVAD, BiVAD, IABP, ECMO
Inability to tolerate face down position
Serious burn (20% body surface area)
Unstable fracture
Spinal instability
Recent sternotomy or major abdominal surgery
Recent tracheostomy
Life-threatening cardiac arrhythmia within 24 h
Bronchopleural fistula

ICP = intracranial pressure; DVT = deep vein thrombosis; LVAD = left ventricular assist device; BiVAD = biventricular assist device, IABP = intraaortic balloon pump; ECMO = extracorporeal membrane oxygenation.

The feasibility and success of the COVID-19 Prone Team has created the possibility of sustaining and even expanding prone positioning capabilities across our hospital network in case of a future crisis. Further education and training can be disseminated to nurses and clinicians working in non-medical ICUs, utilizing some of the training materials and personnel in the COVID-19 Prone Team.

5. Conclusions

During the COVID-19 pandemic, the rapid development and implementation of a mobile prone team allowed for increased capacity to prone patients with moderate-to-severe ARDS in ICUs beyond the MICUs to meet the surge of critically ill patients during the height of the pandemic. This was done effectively and with tolerable adverse outcomes.

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None.

Declaration of Competing Interest

Dr. Brodie receives research support from ALung Technologies, he was previously on their medical advisory board. He has been on the medical advisory boards for Baxter, BREETHE, Xenios and Hemovent. Patrick Ryan reports honorarium from Mölnlycke Health Care. The other authors report no other conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcrc.2020.08.020.

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