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ORIGINAL RESEARCH

Nerve Compression Injuries After Prolonged Prone Position Ventilation in Patients With SARS-CoV-2: A Case Series

Luigia Brugliera, MD, PhD,[a] Massimo Filippi, MD,[b] Ubaldo Del Carro, MD,[c] Calogera Butera, MD,[c] Francesca Bianchi, MD,[c] Paola Castellazzi, MD,[a] Paolo Cimino, MD,[a] Paolo Capodaglio, MD,[d] Giacomo Monti, MD,[e] Pietro Mortini, MD,[f] Luca G. Pradotto, MD,[g,h] Lorenzo Priano, MD,[g,h] Alfio Spina, MD,[f] Sandro Iannaccone, MD[a]

From the [a]Department of Rehabilitation and Functional Recovery, I.R.C.C.S. San Raffaele Scientific Institute, Vita-Salute University, Milan; [b]Neuroimaging Research Unit, Institute of Experimental Neurology, Division of Neuroscience, Neurology Unit, Neurophysiology Unit, I.R.C.C.S. San Raffaele Scientific Institute, Milan, Italy/Vita-Salute San Raffaele University, Milan; [c]Neurophysiology Unit, I.R.C.C.S. San Raffaele Scientific Institute, Milan; [d]Rehabilitation Unit, I.R.C.C.S. Istituto Auxologico Italiano, Piancavallo; [e]Department of Anaesthesia and Intensive Care, I.R.C.C.S. San Raffaele Scientific Institute, Vita-Salute University, Milan; [f]Department of Neurosurgery and Gamma Knife Radiosurgery, I.R.C.C.S. San Raffaele Scientific Institute, Vita-Salute University, Milan; [g]Neurology Unit, I.R.C.C.S. Istituto Auxologico Italiano, Piancavallo, Italy; and [h]Department of Neuroscience, University of Torino, Turin, Italy.

Abstract

Background: Prone positioning improves oxygenation in adult respiratory distress syndrome. This procedure has been widely used during the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic. However, this procedure can also be responsible for nerve damage and plexopathy.

Methods: We retrospectively reviewed a series of 7 infectious patients with coronavirus disease 2019 who underwent prone positioning ventilation at the San Raffaele Hospital of Milan, Italy, during the SARS-CoV-2 pandemic.

Results: Clinical and neurophysiological data of 7 patients with nerve compression injuries have been reported.

Conclusions: Health care workers should take into consideration the risk factors for prone positioning—related plexopathy and nerve damage, especially in patients with coronavirus disease 2019, to prevent this type of complication.

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Prone positioning (PP) has been used since the 1970s to improve oxygenation in adult respiratory distress syndrome (ARDS) and has been intensively applied in intensive care units (ICUs) during the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic.[1] It has been estimated that about 5% of patients with SARS-CoV-2 with ARDS would require mechanical ventilation.[2-4] A recent editorial published in JAMA about PP stated that "tolerance is sometimes a limitation of the technique, the physiological effects are not clarified, and the benefits of very short sessions may be questionable."[4(p2267)] In March 2020, in response to the dramatic number of patients simultaneously requiring ICU admission in Northwestern Europe, Italian hospitals created new units, specifically dedicated to the treatment of critical patients with SARS-CoV-2.[5-7] This extraordinarily high need for intensive care during the pandemic peak generated a series of health management issues. Several ICU workers, not routinely devoted to ARDS management, were not familiar with PP procedures. The total amount of hours spent in the prone position per cycle (16h/d) could therefore show high interindividual variability. Because of the overload of patients' admissions and the increased need for lung ventilation, some patients did not undergo several PP cycles per day, as required, whereas other patients benefited

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from extended pronation protocols, sometimes outlasting 16 hours per day. Prolonged static position on intensive care beds increases patient's exposure to localized compression in specific body areas. In the particular case of PP associated with ARDS-related mechanical ventilation, complications due to prolonged exposure have been previously described.[8,9] According to the guidelines of the German Society of Anaesthesiology and Intensive Care Medicine, nerve compression injury after prolonged PP is a very rare condition (evidence level 2b).[10] However, the same authors commented that the incidence of PP-related complications had not been sufficiently studied and that further investigations were needed.[10] To present further evidence of PP-related complications, we retrospectively collected data from 7 critically ill patients with SARS-CoV-2 who were intubated and mechanically ventilated in a prone position for a prolonged time at the ICU of the San Raffaele Hospital (Milan, Italy) and consecutively transferred to the Rehabilitation Unit of the same hospital.[5]

Case series

Case 1: Bilateral axillary, suprascapular nerves' lesion, and bilateral mononeuropathy of ulnar nerve proximal to the elbow

A 40-year-old man with SARS-Cov-2 pneumonia received mechanical ventilation for 19 days. Initially, noninvasive ventilation (NIV) was applied for 2 days. After the worsening of his respiratory failure, the patient was intubated and invasive ventilation (IV) in PP was applied for 17 days. After pulmonary distress resolution, the patient complained of proximal hyposthenia of both upper limbs and paresthesia of the hands. Electromyography (EMG) revealed acute denervation (ie, fibrillation potentials) of bilateral deltoids, supraspinatus and infraspinatus muscles, abductor digiti minimi, and flexor carpi ulnaris. No further denervation was observed in the remaining upper limb muscles or the cervical paraspinal or serratus anterior muscles. Electroneurography evidenced a reduction of ulnar sensory action potential (SAP) amplitude without focal motor conduction slowing. The patient was thus diagnosed as having bilateral axillar and suprascapular axonal damage associated with bilateral mononeuropathy of the ulnar nerve, proximal to the elbow.

Case 2: Bilateral ulnar nerve neurapraxia at the elbow level

A 55-year-old man with SARS-Cov2 pneumonia underwent IV in PP for 7 days. After ceasing sedation, the patient presented with bilateral hypoesthesia of the fifth fingers. No risk factors for compressive neuropathy were identified, apart from the presence of a hematoma in the left deltoid muscle, apparently unrelated to the clinical findings. Nerve conduction measurements showed a bilateral slowing of motor and sensory ulnar nerve velocity around the elbow (in the segment from above to below the elbow). Needle EMG revealed a moderately decreased recruitment pattern in the first dorsal interosseous muscle, bilaterally. Positive sharp waves, or fibrillation potentials, were absent. These findings supported the diagnosis of focal neurapraxia of both ulnar nerves at the elbow level.

List of abbreviations:

ARDS	adult respiratory distress syndrome
EMG	electromyography
FDI	first dorsal interosseous
ICU	intensive care unit
IV	invasive ventilation
NIV	noninvasive ventilation
PP	prone positioning
SAP	sensory nerve action potential
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2

Case 3: Axonotmesis of the left ulnar nerve

A 47-year-old man with SARS-Cov2 pneumonia underwent IV in PP for 19 days. While undergoing IV, the patient went into a septic state. After regaining consciousness, the patient had hyposthenia and hypoesthesia of his left upper limb. Compound muscle action potential could not be recorded from abductor digiti minimi and first dorsal interosseous (FDI) muscles, both with distal and proximal sites of stimulation. Distal SAPs of the left ulnar nerve were also absent. Conduction studies of the left axillary, left radial, right ulnar, and right and left median nerves, together with F-wave evoked by left median nerve stimulation were within the normal ranges. Needle examination in abductor digiti minimi, FCU, and FDI muscles showed fibrillations during the resting phase and no motor unit action potentials during the recruitment phase. Overall, these findings indicated a complete axonal lesion of the left ulnar nerve at the elbow level, or proximally.

Case 4: Left brachial plexopathy (upper trunk)

A 51-year-old man with noninsulin-dependent diabetes mellitus was diagnosed as having SARS-Cov2 and developed pneumonia. The patient received hydroxychloroquine 400 mg, lopinavir 400 mg, and ritonavir 100 mg per day. Because of a worsening of his respiratory function, mechanical ventilation (NIV for 6d and IV for 8d) was performed in PP for 14 days. After ceasing sedation, the patient presented with hyposthenia of the left upper limb. Motor and sensory nerve conduction studies of the median and ulnar nerves, motor conduction study of the left axillary nerve, and F-wave evoked by the stimulation of the left median and ulnar nerves were within normal ranges, bilaterally. Needle examination of the left supraspinatus, infraspinatus, deltoid, biceps brachii, and brachioradialis muscles showed active denervation during the resting phase and moderate reduction of motor unit action potentials' recruitment during maximal contraction. No denervation of cervical paraspinal muscles and left serratus anterior muscles was observed. Overall, these findings indicated acute partial axonal damage of the upper trunk of the left brachial plexus.

Case 5: Right brachial plexopathy (rostral portion), possible overlap with right musculocutaneous nerve injury; left lumbosacral plexopathy

A 61-year-old man complained about hyposthenia of his right upper limb and left lower limb after discharge from the ICU. The patient had been diagnosed as having SARS-Cov-2 pneumonia and received NIV for 22 days, 9 of which in PP. A hematoma in the anterior compartment of the right arm was observed.

Neurophysiological measurements showed a complex clinical picture. Electroneurography evidenced normal conduction parameters, except for focal entrapment of the right ulnar nerve at

Table 1 Summary of clinical characteristics of the series

Case	Sex/Age (y)	Comorbidity	Weight Loss (kg) (% Loss in the Last 3mo)	Pronation Time (d)	MUST at Hospitalization	Nerve Injuries
1	M/40	H	20 (−18.3)	17	2	BIL axonotmesis C5 root; BIL axonotmesis ulnar nerve at elbow
2	M/55	None	8 (−10)	7	0	BIL neurapraxia of ulnar nerve at elbow
3	M/47	None	10 (−11.2)	19	0	L axonotmesis of ulnar nerve at elbow
4	M/51	D	10 (−13.3)	14	2	L brachial plexopathy
5	M/61	TT	20 (−18.1)	9	2	L lumbosacral plexopathy or L4-L5-S1 radiculopathy; R brachial plexopathy or C5-C6-C7 radiculopathy
6	M/76	H, D, CRF	17 (−18.2)	16	2	R neurapraxia of ulnar nerve at elbow; R axonotmesis of peroneal nerve at the popliteal fossa/fibular head
7	M/43	H	10 (−12)	13	2	R axonotmesis of ulnar nerve at elbow

Abbreviations: BIL, bilateral; CRF, chronic renal failure; D, diabetes mellitus; H, hypertension; L, left; M, male; MUST, Malnutrition Universal Screening Tool; O, obesity; R, right; TT, thalassemia trait.

the elbow and right median nerve at the wrist. There were also reductions of compound muscle action potential amplitude over the left sciatic popliteus externus nerve and SAP over the left sural nerve. EMG showed a reduction of spatial recruitment of the right brachioradialis, flexor carpi radialis, and triceps brachii with complete denervation of biceps brachii. In the lower limbs, EMG evidenced almost complete denervation (ie, acute denervation and no voluntary activity) of left tibialis anterior, left gluteus medius, and left peroneus longus muscles. No spontaneous activity was evidenced in lumbar paraspinal muscles.

These findings suggested a marked axonal lesion of the left lumbosacral plexus and a mild neurapraxic lesion of the right brachial plexus (upper and medium trunks), with overlying complete damage of the right musculocutaneous nerve (probably due to upper limb hematoma).

Case 6: Neurapraxia of the right ulnar nerve at elbow level and moderate impairment of the right median nerve at the wrist; axonotmesis of the right peroneal nerve at the popliteal fossa/fibular head

A 76-year-old man with noninsulin-dependent diabetes mellitus and chronic renal failure developed SARS-CoV-2 pneumonia. The patient had been treated with mechanical ventilation for 37 days (NIV for 21d and IV for 16d) and had been prone positioned for a total of 16 days. After regaining consciousness, the patient presented with right upper and lower limbs hyposthenia.

The neurophysiological investigations revealed a moderate focal entrapment of the right ulnar nerve at the elbow and the right median nerve at the wrist, while at the lower limb, an almost complete focal axonal lesion of the right sciatic popliteus externus nerve was observed over the fibular head.

Case 7: Focal right ulnar nerve impairment at the elbow

A 43-year-old man with SARS-Cov2 pneumonia underwent IV in PP for 13 days. After regaining consciousness, the patient complained about hyposthenia of his right hand and hypoesthesia of the ulnar side and fifth finger of his right hand. The neurologic examination showed a moderate hyposthenia and hypotrophy involving the interosseous, the ulnar lumbrical, and the hypothenar muscles of his right hand. A deficit of the adductor pollicis muscle was also observed with the "signe de journal," thus suggesting a right ulnar injury. Nerve conduction study showed focal entrapment of the right ulnar nerve at the elbow. Needle electromyography revealed, in the right FDI, moderately decreased recruitment patterns and fibrillations during the resting phase. These findings suggested the presence of a right ulnar nerve axonal and neurapraxic impairment at the elbow level.

Discussion

Positions that appear to cause brachial plexopathy include upper limb abduction with external rotation and posterior shoulder displacement for periods as short as 45 minutes.[8,10] General anesthesia and malpositioning increase the risk of nerve injury because of the loss of normal muscle tone as well as the patient's inability to report discomfort. The prevalence of nerve injuries due to operative positioning was estimated at around 0.14%. Most cases (38%) consisted of brachial plexopathies after sternotomy.[8] Recovery occurred typically within 6 months in 92% of patients.[8] Prolonged immobilization in intensive beds can increase the risk of skin pressure necrosis and localized nerve compression. So far, in the largest study of PP, Gattinoni et al found complications related to skin pressure in 36% of patients.[8] In 2002, Goettler et al reported brachial plexopathy in 2 patients with ARDS after prolonged PP in ICU.[3] Turning the patient's head to the opposite side has been suggested to increase the stretch, but this was not confirmed by a cadaveric study.[8] Compression neuropathies after IV with PP have been so far considered as rare conditions.[3,10] However, in the 2 months of SARS-CoV-2 peak pandemic in northern Italy, 7 cases of compression injuries of 135 patients who underwent IV in PP have been observed. All of the 7 patients were male. Prevalence of the condition among patients with SARS-CoV-2 discharged from ICU was therefore about 5%. Several factors may have accounted for such complications. It is known that male patients are more likely to develop compression neuropathies than female patients.[11] Moreover, male patients would need high-level and longer-lasting IV than female patients

in the ICU.[11] Genetic and metabolic factors, in particular obesity and diabetes, may also have facilitated the occurrence of this complication. Abnormal anatomy may also contribute to the risk of neuropathy. Four of the 7 patients presented 1 risk factor, and 1 patient had 2 risk factors (table 1). We can thus conclude that extra care during prolonged PP procedures must be applied in patients presenting with 1 or more risk factors for nerve injury. SARS-CoV-2 infection in combination with IV in PP seems to increase the risk of developing compression nerve injuries. PP procedures require expert skills. Extra care must be taken with arm positioning and motion while patients are prone. The positioning of the chest roll and the type of surface the patient is placed on must be evaluated to ensure that the shoulders are not posteriorly extended. Proper positioning and rolling technique may decrease the risk of brachial plexopathy. Therefore, a well-trained health care team is mandatory to perform such procedures. This has certainly represented a critical issue during the recent pandemic.

The important weight loss in our patients may also have played a role as a potential contributing factor.[12] All patients reported a low body mass index and risks of malnutrition, according to the Malnutrition Universal Screening Tool score. Such factors can increase risk for nervous system damage.[13] Indeed, excessive weight loss leads to the decrease of the fatty cushion protecting the nerve, which can predispose to a mechanical nerve injury.[12] Furthermore, altered nutritional status can increase the probability of nerve damage or plexopathy.[13,14]

In conclusion, despite compressive neuropathies generally being held as rare complications of IV with PP, evidence brought up by the recent SARS-CoV-2 pandemic has shown that such conditions are more frequent than previously understood. Risk factors should be carefully identified and taken into account to prevent nerve damage. Based on this limited experience, patients with 1 or more risk factors and poor body mass index should undergo shorter PP cycles to reduce the risk of plexopathy. More investigations and retrospective studies are needed to define the exact prevalence of this complication.

Keywords

Brachial plexus; Coronavirus; Prone position; Rehabilitation

Corresponding author

Luigia Brugliera, MD, PhD, Department of Rehabilitation and Functional Recovery, I.R.C.C.S. San Raffaele Scientific Institute, Vita-Salute University, Via Olgettina 60, 20132, Milan, Italy. *E-mail address:* brugliera.luigia@hsr.it.

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