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Case Report

Rehabilitation in a Patient with Spastic Quadriplegia and Pneumonia: The Physiatrist's Point of View Through the Analysis of a Case Report

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Abstract

Patients with severe neurological sequelae often experience profound motor deconditioning that, combined with impaired mucociliary clearance, reduced lung volume, and the presence of tracheostomy, predisposes them to pulmonary infections and serious respiratory complications. A 24-year-old male with spastic quadriplegia secondary to childhood cerebral hemorrhage from an arteriovenous malformation, tracheostomy with a cuffed cannula under mechanical ventilation, and hydrocephalus treated with a ventriculoperitoneal shunt, presented to the emergency department with fever unresponsive to paracetamol and ceftriaxone. Laboratory tests showed markedly elevated inflammatory indices (C-reactive protein 249.3 mg/dl), and chest computed tomography revealed extensive consolidation of the left lower lobe with an air bronchogram and endobronchial obstruction, consistent with aspiration pneumonia. Fibrobronchoscopy confirmed the presence of endobronchial material, and culture grew Acinetobacter baumannii. Given the patient's clinical and functional status, the physiatrists prescribed an Individual Rehabilitation Project (motor and respiratory re-educational programs, including passive mobilization of major joints, cautious trunk stabilization, and lung volume recruitment maneuvers) to support the effects of positive-pressure ventilation. The case underscores the dual challenge of neurological impairment and pulmonary vulnerability, where immobilization further exacerbates respiratory compromise and infection risk, fostering sarcopenia and poor quality of life. In patients with spastic quadriplegia of cerebrovascular origin on long-term mechanical ventilation, a synergistic approach combining NIV optimization and individualized motor-respiratory rehabilitation may represent an effective strategy to control recurrent infections and maintain clinical stability. In this area, there is currently insufficient evidence, and urgent future research is needed.

Keywords
Pneumonia; spastic quadriplegia; tracheostomy; positive pressure ventilatory treatment; rehabilitation

1. Introduction

Physiatrists frequently encounter patients with neurological conditions that not only impair motor function but also compromise respiratory function [1]. This deconditioning significantly impacts respiratory muscles, leading to a decline in overall health and the potential need for mechanical ventilation. While crucial, mechanical ventilation itself carries risks, including increased susceptibility to infections. In fact, ventilator-associated pneumonia is a complication that patients undergoing endotracheal intubation may experience [2]. Despite conflicting evidence, respiratory re-education through physiotherapy has been widely used as an adjunctive treatment for adults with pneumonia, particularly in cases of ventilator-associated pneumonia [3, 4]. Physiatrists establish physiotherapy goals for these patients to optimize respiratory function and overall well-being. These goals include maintaining lung volume to prevent atelectasis, improving gas exchange through enhanced oxygenation and ventilation, and clearing airway secretions to minimize the risk of infection. Furthermore, physiotherapy seeks to reduce the work of breathing by strengthening inspiratory muscles and facilitating more efficient respiratory mechanics [5]. In mechanically ventilated patients, whether intubated or with tracheostomies, physiotherapy aims to minimize the duration of mechanical ventilation and prevent ventilator-associated complications. Ultimately, the goal is to maximize skeletal muscle function, promote functional independence, and improve the overall quality of life for these individuals [6].

A case of a patient with severe neurological and respiratory complications is presented, aiming to determine the most appropriate personalized treatment plan and review the available literature on similar cases.

2. Case History

A young patient with spastic quadriplegia, secondary to a cerebral hemorrhage caused by a ruptured arteriovenous malformation (AVM), treated at a children’s hospital with subsequent development of hydrocephalus and left ventriculoperitoneal shunt placement, was admitted to the Emergency Department (ED) of Tor Vergata University Hospital (TVUH) due to recurrent pneumonia. His neurological picture had been assessed using imaging techniques. On computed tomography (CT) in various scanning planes (axial, sagittal, and coronal), occipital craniotomy findings are observed with extensive gliotic-malacia findings in the bilateral cerebellar region. Ex vacuo dilation of the fourth ventricle is also observed (anterior-posterior diameter approximately 33 mm) with compressive effects on the pons and medulla oblongata. The pons and medulla oblongata exhibit heterogeneous hypodensities. Hydrocephalic dilation of the supratentorial ventricular system. Presence of a ventriculoperitoneal shunt with craniotomy access in the left frontal region and distal apex corresponding to the septum pellucidum. Dilation of the third cerebral ventricle. On the sagittal plane, using the same technique, the presence of a ventriculoperitoneal shunt is visible on the sagittal plane. The evaluation of the central nervous system and hydrocephalus was completed by magnetic resonance imaging (Figure 1).

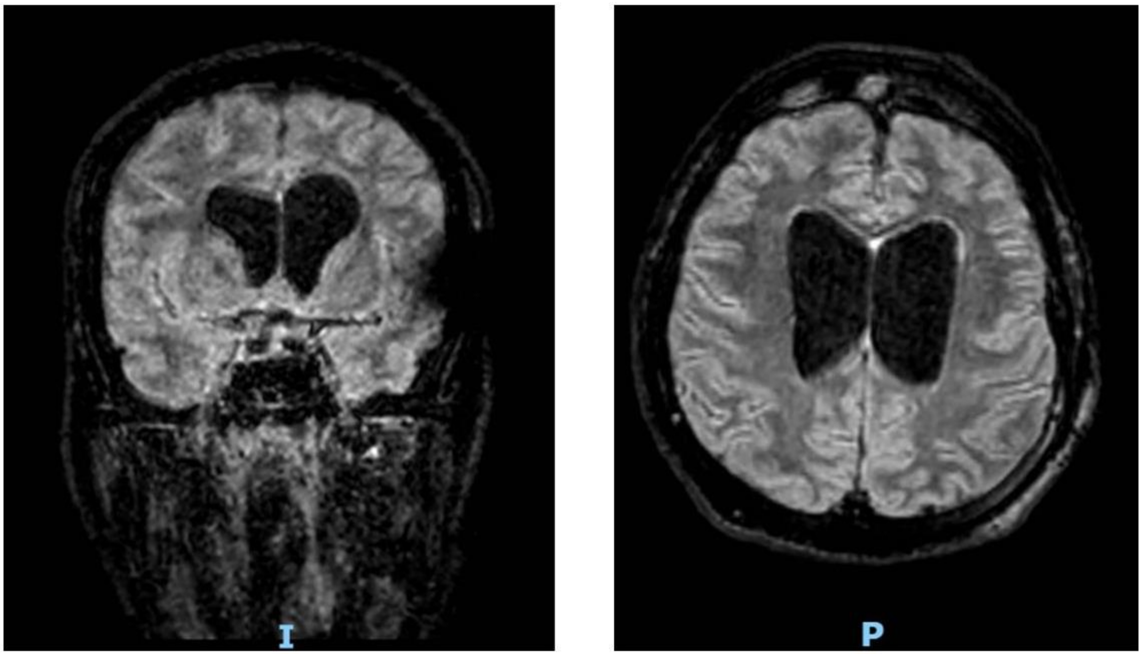

Figure 1 Magnetic Resonance Imaging (MRI) of the patient.

A CT study of the abdomen was also done. The examination revealed abundant fecal residue in the descending colon and sigmoid colon, with fecal impaction in the rectal ampulla. The examination also revealed the presence of a radiopaque catheter that, running through the soft tissues of the left anterior thoracic region, enters the abdomen at the left iliac fossa, and terminates in the pelvis: a finding consistent with ventriculoperitoneal shunting. Minimal fluid in the left iliac fossa.

Three years before the patient's current hospitalization, they underwent a sleep study in the Pulmonology department. The study revealed the presence of obstructive sleep apnea/hypopnea syndrome (OSAHS), with a borderline number of significant events and no severe apneas.

Recent clinical history: Two months before this admission, the patient presented to a different institution's ED with dyspnea and fever. Investigations revealed bilateral pneumococcal pneumonia (Figure 2).

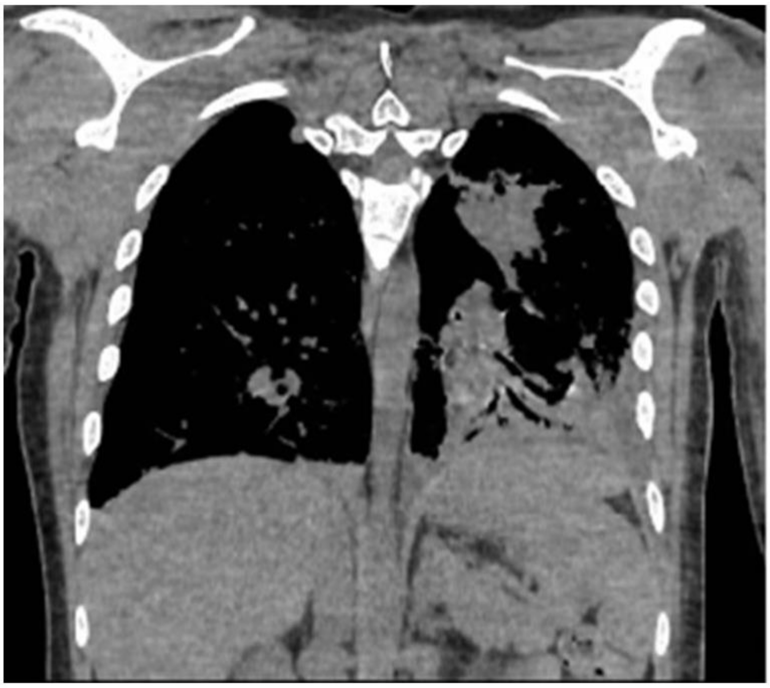

Figure 2 Results of the young patient's first thoracic computerized tomography (CT) scan.

The patient received antibiotic therapy and non-invasive ventilation (NIV). Subsequently, he was transferred to the Intensive Care Unit (ICU), where blood cultures grew methicillin-resistant Staphylococcus aureus (MRSA). Targeted antibiotic therapy was initiated. To deliver respiratory support, the patient underwent tracheostomy, while a percutaneous gastrostomy (PEG) was inserted to provide enteral nutrition. The patient subsequently developed ventilator-associated pneumonia caused by Stenotrophomonas maltophilia and Acinetobacter baumannii, treated with Cefiderocol. Following this, the patient was transferred to the R1 department. In Italy, R1 departments are high-intensity residential nursing home units, dedicated to non-acute patients with complex needs and support for vital functions, such as ventilation, tracheostomy, or artificial nutrition, with 24-hour nursing staff and immediate medical assistance. R1 department is part of the services of the National Health Service for non-self-sufficient individuals with severe disabilities or clinical instability, when home care is not feasible. A week later, the patient underwent a PEG dislocation, necessitating another hospitalization. During this hospitalization, the patient was diagnosed with anthropyloric edema, leading to the removal of the PEG tube. PEG replacement was postponed due to a suspected infectious process. A peripherally inserted central catheter (PICC) was inserted to provide parenteral nutrition, and the patient was transferred back to the R1 department.

The patient, recently tracheostomized for respiratory failure via a percutaneous stoma with a Rüsch model cuffed cannula and on mechanical ventilation, started showing symptoms of pneumonia (i.e. recurrent fever unresponsive to paracetamol and ceftriaxone therapy) and was thus admitted to TVUH. A timeline of the case is presented in Table 1.

Table 1 Case report timeline.

Timepoint	Event
T–24 months (approx)	Sleep study: diagnosis of OSAHS (borderline events, no severe apneas)
T–2 months	ED admission (other institution): dyspnea and fever; bilateral pneumococcal pneumonia
T–2 months (during ICU stay)	ICU transfer: MRSA bacteremia; targeted antibiotic therapy initiated
T–2 months (during ICU stay)	Tracheostomy (cuffed cannula) and PEG placement for enteral nutrition
T–2 months (post-ICU)	VAP: Stenotrophomonas maltophilia + Acinetobacter baumannii → Cefiderocol
T–2 months (post-ICU)	Transfer to R1 high-intensity residential unit
T–1 week	PEG dislocation → re-hospitalization; anthropyloric edema → PEG removal; PICC placement; parenteral nutrition; transfer back to R1
T0 – ED Admission at TVUH	ED admission at TVUH: fever unresponsive to paracetamol + ceftriaxone; CRP 249.3 mg/dL; chest CT: left lower lobe consolidation + endobronchial obstruction
	Fibrobronchoscopy: BAL culture positive for Acinetobacter baumannii
	Blood cultures: S. hominis, S. capitis (peripheral + PICC); Candida glabrata (PICC + urine); Candida tropicalis (urine)
	Antibiotic regimen: piperacillin/tazobactam + vancomycin (CoNS bacteremia) + caspofungin (candidemia); antibiogram extended → tigecycline + ampicillin/sulbactam + cefiderocol + fosfomycin
T0 + 1 week	NIV via tracheostomy initiated (BiPAP: iPAP 15 cm H_2O, PEEP 5 cm H_2O); SNG feeding started; PICC removed
T0 + 1-2 weeks	PRM consultation: physiatric assessment; MAS scored (L-UL: 3, R-UL: 1, L-LL: 4, R-LL: 0); IRP prescribed
T0 + 2 weeks	IRP started: passive ROM all 4 limbs, trunk stabilization, lung volume recruitment, manually assisted cough, mechanical insufflation-exsufflation (Cough Assist), postural drainage
T0 + 2-3 weeks	Clinical stability achieved: no new infectious events; GCS 15 stable; hypercapnia improving; accessory muscle use reduced; ventilation shifted to PCV mode (2 L/min)
T0 + 3-4 weeks	Spasticity improvement (MAS 3 lower limbs); weight gain +2 kg; total proteins normalized; hemoglobin 9.6 → normalization trend
T0 + ~6 weeks - Discharge	Discharge to RSA: CRP 35 mg/dL; Hb improved (7.4 → 9.6 g/dL); BP 130/80 mmHg; SpO_2 100%; GCS 15; eupneic on room air + ventilator; tracheostomy and PEG retained

Chest Computerized Tomography (CT) showed a parenchymal consolidation involving almost the entire left lower lobe of the lung, with an air bronchogram sign in the context; a portion of endobronchial material involving the distal third of the ipsilateral main branch and almost the entire course of the lower lobe branch and its segmental branches was present (Figure 3). Multiple areas of increased ground glass density also appeared, some more consolidated with a pseudonodular appearance and some with a flowering tree shape, corresponding to the apical segment of the left upper lobe, the lingula, the anterior and posterior segments of the right upper lobe, and at the level of the medial segment of the middle lobe. Multiple clean cylindrical bronchiectases were associated, particularly noticeable in correspondence with the lingula. These findings were related to a probable aspiration pneumonia.

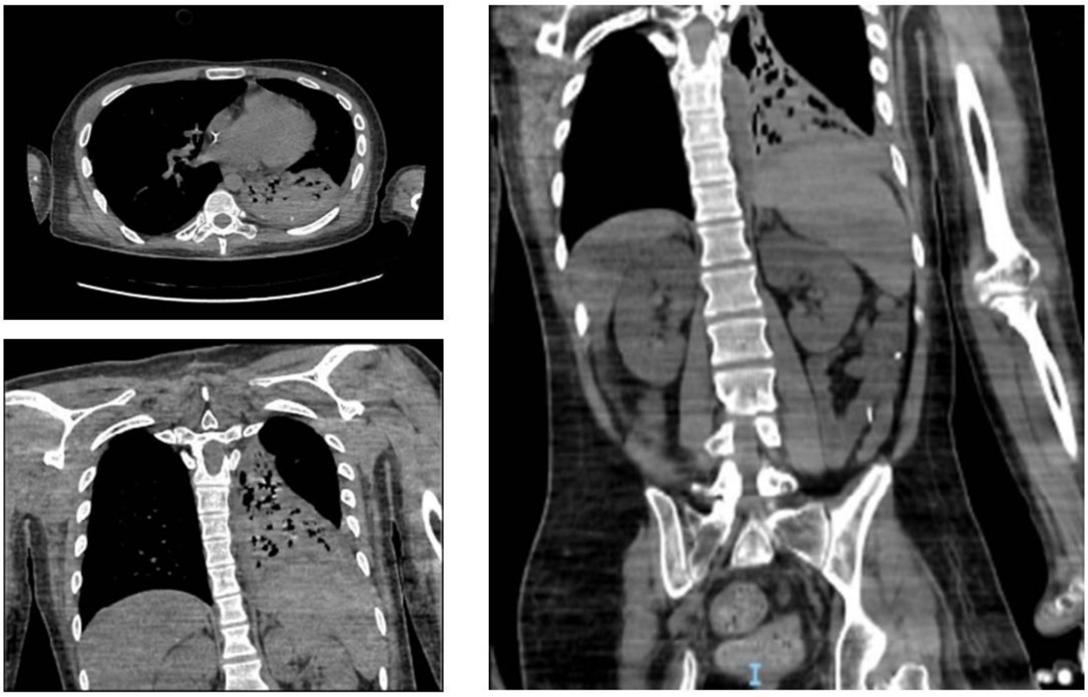

Figure 3 Results of the young patient's thoracic computerized tomography (CT) scan performed in case of fever resistant to paracetamol and ceftriaxone.

In addition, numerous blood, urine, and infectious culture tests were performed with the following results: urine culture positive for Candida Tropicalis; blood cultures from peripheral vein positive for S. hominis and S. capitis; blood cultures from PICC positive for S. hominis, S. capitis, and Candida glabrata; urinary antigen for Legionella and Pneumococcus negative. Finally, a fibrobronchoscopy was performed on the patient with a negative culture sample for acid-fast bacilli but with a positive Acinetobacter Baumannii culture. The antibiogram was characterized by the presence of resistance to carbapenems and sensitivity to colistin/cefiderocol. Different antibiotic therapies were started: piperacillin/tazobactam for pneumonia, vancomycin for subsequent Clostridioides difficile bacteremia, and caspofungin for Candida Glabrata candidemia. The finding of A. baumannii on the cultured bronchoalveolar lavage fluid (BAL), the positivity of the blood cultures for Candida glabrata, Staphylococcus hominis, and Staphylococcus capitis, and the positive urine culture for Candida glabrata suggested extending the antibiogram for Acinetobacter baumannii, opting for a therapy with tigecycline, ampicillin/sulbactam, cefiderocol, and fosfomycin. Due to severe protein-calorie malnutrition and considering the previous PEG-related complications, PICC was removed, and nasogastric tube feeding was initiated to continue enteral nutrition. The radiological examination documents the slightly increased hypodiaphany of the lung parenchyma projectively in the left mediobasal area associated with an ipsilateral pleural effusion layer, slightly increased compared to the previous one. No pleuro-parenchymal alterations are radiographically appreciable on the right. Unchanged, slight shift of the mediastinal structures towards the left. The tracheostomy tube is projected to be in place. Nasogastric tube with the distal end projecting into the gastric body. Ventriculo-peritoneal shunt is confirmed prospectively in the left hemi-side (Figure 4A).

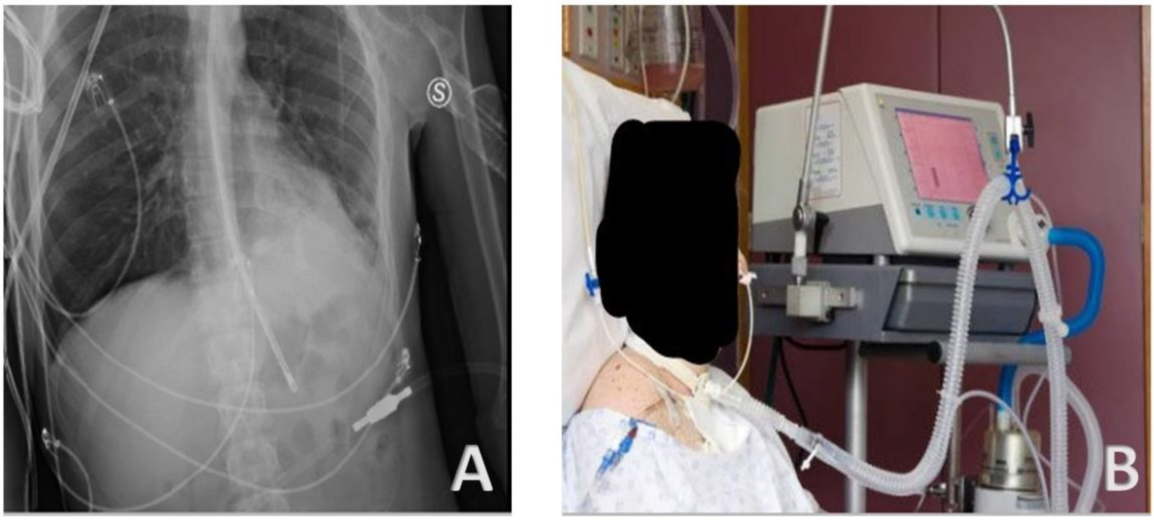

Figure 4 (A) Radiological picture of a bedside chest x-ray; (B) Mechanical ventilation system connected to the tracheostomy. The respiratory assistance technique is described for the patient who has been taken into care. For further clinical implications, see also the main text of the described clinical case.

An opening is made in the tracheal wall and skin, with consequent communication between the cervical trachea and the external environment, allowing air to ensure effective breathing. The patient was provided with a Rüsch inflated cannula. Cuffed tracheostomy tubes, in addition to allowing airway clearance like the others, protect the patient from inhalation (of saliva, food material, or gastric origin) and are particularly suitable in mechanical ventilation, as they eliminate air leaks from the upper airways. With the cuff inflated and the non-fenestrated inner cannula inserted, it is possible to connect the patient to the mechanical ventilator: with the fenestrated inner cannula in place, in fact, the insufflated air would partially take the route of the upper airways (via the holes), causing significant venting and decreasing the tidal volume. The NIV device is positioned a short distance away and connected to the tracheostomy via a double corrugated tube. Invasive mechanical ventilation was set with the following parameters: positive airway pressure (iPAP): 15 cm H_2O; positive end-expiratory pressure (PEEP): 5 cm H_2O. Given the patient’s stable clinical condition, including normal respiratory rate and acceptable vital signs as monitored continuously, the decision was made to maintain eupneic ventilation NIV connected to the tracheostomy without supplemental oxygen therapy (Figure 4B). Contact isolation precautions were continued, and close microbiological monitoring was implemented.

The Physical and Rehabilitation Medicine (PRM) Unit of TVUH (i.e., the authors of this report) was consulted as part of the multidisciplinary management of this complex patient. Before proceeding with the physiatric examination, the patient's pelvis CT scan was examined to better assess the musculoskeletal situation in that area, and then compared with the objective findings found during the visit. The examination shows an angulated appearance of the sacrococcygeal joint. Furthermore, the presence of numerous coarse, contiguous, intracapsular calcifications is documented at the right coxofemoral joint at the level of the superior acetabular margin (causing compression of the adductor lodge on the homolateral side at the level of the adductor magnus). There is also subtle osteoarthritis at the level of the sacral wings at the level of the first two bones (consistent with a likely initial condition of osteoporosis).

Patient, still in contact isolation, was examined in bed in forced semi-orthopneic decubitus with the bed positioned at 45°. Although the overall clinical condition appeared to have worsened, the patient's status remained stable despite the severity of the illness. The patient exhibited a malnourished phenotype characterized by generalized thinness and reduced muscle mass. Despite this, the patient remained alert and cognitively intact. Although spontaneous speech was not observed, the patient demonstrated responsiveness to verbal commands with normal vocal intensity, exhibiting mimetic responses. The patient was cooperative and followed simple commands to the best of his ability. Orientation to person, place, and time could not be assessed due to the patient's clinical condition. Ocular examination revealed eyes aligned in the orbits, spontaneously open with a brisk blink reflex. Pupillary reflexes were intact with normal constriction to light. The patient demonstrated smooth pursuit eye movements, tracking a visual target in all directions. Head rotation was possible in response to verbal commands, with a slightly greater range of motion to the right compared to the left. This asymmetry may be attributed to the presence of the double corrugated tube connected to the tracheostomy for NIV, which slightly restricted head movement to the left. He was able to move his trunk laterally to the right with compensatory strategies, crawling on the bed, without rotation on the pelvis. The inspection revealed continuous multiparametric monitoring, a bladder catheter and nasogastric tube, and an NIV device connected to the stoma in the neck. The trunk appeared to be slightly hyperextended and slightly laterally inclined to the left. No edema was observed in the four limbs. The left upper limb showed a flexed posture at the elbow and wrist with a hypertonic hemiplegic hand. The first finger was held in adduction, and the remaining four fingers were flexed at the proximal and distal interphalangeal joints. The patient exhibited an inability to grasp and release objects, with both grip strength and manual dexterity being unassessable. The left upper limb was held in adduction towards the trunk; passive mobilization of the limb produced an abduction from the trunk up to about 10°, elbow flexion to medium degrees, shoulder flexion to medium degrees, with no pain and soreness but with diffuse hypertonia [modified Ashworth Scale (MAS): 3]. The right upper limb demonstrated moderate flexion at the shoulder and elbow. The hand exhibited possible dorsiflexion at the wrist with flexion-abduction of all fingers. Although grip strength and manual dexterity could not be formally assessed, the patient demonstrated the ability to grasp by touching the thumb to the index finger, forming a circle (the "okay sign"). The right upper limb also showed a mild hypertonic rigidity (MAS 1). The movements of abduction at medium degrees and flexion of the shoulder, elbow, and wrist were possible without pain/tenderness. The left lower limb exhibited slight flexion at the hip and knee with a knee extension deficit of approximately 5 degrees. A soft anti-decubitus cushion was placed beneath the popliteal fossa. The foot demonstrated dorsiflexion with the heel protected by a clean dressing. Passive correction of the foot position was not possible. Passive mobilization of the left lower limb was hindered by the presence of spastic hypertonicity (MAS 4). Still, the limb was mobilized until reaching a passive flexion of the hip and knee of 90°, with intra- and extra-rotation of the hip possible but limited to the first degrees, in the absence of pain/tenderness. The right lower limb appeared to be in slight flexion and external rotation of the hip and knee flexion without any objectifiable knee extension deficits in active movement; the foot was in slight eversion. No spastic hypertonicity was observed in this area at rest or during attempts at active mobilization, which the patient was able to perform with hip and knee flexion up to medium degrees without pain; during passive movement of the right lower limb, there was the appearance of myoclonus spread throughout the limb; however, the limb was passively mobilizable on all planes of space without accentuation of the hypertonicity. The plantar cutaneous reflex (PCR) was mute on the left foot, present in flexion on the right. Sensory examination revealed no apparent sensory deficits. The patient showed intact tactile sensitivity in the assessed dermatomes, with no observable differences in sensory perception between the two sides of the body. A summary of the clinical and functional status of the patient is reported in Table 2.

Table 2 Summary of the clinical and functional status of the patient.

Rehabilitation Domain	Current Status
Airway/Respiration	Tracheostomy (cuffed Rüsch cannula); NIV via tracheostomy maintained in eupnea without supplemental O_2; ventilator parameters: iPAP 15 cm H_2O, PEEP 5 cm H_2O; secretion management program planned (lung volume recruitment, manually assisted cough)
Cranial Nerves/Ocular Motor	Eyes aligned; spontaneous opening with brisk blink; pupils reactive to light; head rotation better to the right than left.
Trunk Control	Able to initiate lateral trunk movement to the right using compensatory bed-crawling strategies
Left Upper Limb	Posture: shoulder adducted to trunk; elbow and wrist flexed; thumb adducted; fingers flexed at PIP/DIP; passive abduction from trunk to 10°; shoulder/elbow flexion to mid-range; no pain; marked hypertonia
	MAS 3: considerable increase in tone; passive movement difficult; consistent with increased resistance to passive movement documented by MAS usage in clinical rehab settings
Right Upper Limb	Posture: moderate flexion at the shoulder and elbow; wrist dorsiflexion possible; finger flexion-abduction posture; abduction and flexion at the shoulder-elbow-wrist to mid-range without pain; fine motor: forms “OK sign” (thumb–index pinch)
	MAS 1: slight increase in tone; mild hypertonic rigidity; functional grasp initiation present
Left Lower Limb	Posture: slight hip and knee flexion with 5° knee extension deficit; foot held in dorsiflexion; heel protected; passive correction of foot

	position not possible; passive hip/knee flexion achievable to 90°; hip IR/ER only first degrees; no pain
	MAS 4: limb rigid in flexion/extension; severe spastic hypertonia limiting passive correction; high risk for contracture; pressure offloading under the popliteal fossa in place
Right Lower Limb	Posture: slight hip external rotation and knee flexion; foot slight eversion; active hip/knee flexion to mid-range without pain; full passive ROM on all planes; myoclonus appears during passive movement
	No spasticity observed
Reflexes	Plantar cutaneous reflex: left mute; right flexor; consistent with asymmetric corticospinal involvement
Sensory Status	Intact light touch across assessed dermatomes; no lateralized sensory deficits observed
Functional Communication/Cognition	No spontaneous speech; responds to verbal commands with normal vocal intensity and appropriate facial mimicry; cooperative and follows simple commands.

An Individual Rehabilitation Project was thus designed, according to the clinical and functional conditions of the patient [7, 8]. A comprehensive motor re-educational program was provided. This program incorporated a passive range-of-motion exercise for all four limbs to maintain joint mobility. Trunk stabilization exercises were included to enhance core strength and stability. A respiratory program was provided, including lung volume recruitment maneuvers to improve lung expansion, manually assisted cough techniques to facilitate airway clearance, and mechanical insufflation-exsufflation to assist in the expectoration of secretions. We decided to use the Cough Assist device for this patient. Since bronchoscopy revealed a positive culture from the bronchoalveolar lavage, a therapeutic lavage was performed to remove the material. Mechanical insufflation-exsufflation (Cough Assist) is indicated for clearing bronchial secretions in patients with an ineffective cough caused by neuromuscular or pulmonary diseases, both noninvasively and invasively. A therapeutic flush is a medical procedure aimed at removing organic material and/or exudate. It was done to reduce the microbial load and remove debris, facilitating healing and proper function of the tracheostomy device, too. The patient in question was therefore a typical candidate for this type of rehabilitation approach, as the cough-generating mechanism is impaired and the patient's respiratory muscles are weak, unable to effectively clear secretions on their own. Postural variations and cautious postural drainage were implemented to promote lung expansion and facilitate the weaning process from non-invasive ventilation.

The IRP implemented for this highly complex patient proved fundamental in maintaining clinical stability and preventing further complications. Throughout treatment, no new infectious events were documented, confirming the efficacy of contact isolation measures and continuous respiratory management, including lung volume recruitment, assisted cough, and mechanical insufflation-exsufflation. The systematic use of passive range-of-motion exercises preserved joint mobility and helped minimize musculoskeletal complications, such as contractures and pressure ulcers, while postural adjustments promoted adequate pulmonary ventilation. Importantly, the patient maintained stable vital signs without worsening respiratory function despite prolonged ventilatory support.

The described settings indicate a Bilevel Positive Airway Pressure (BiPAP) ventilation mode, often used for non-invasive support, where an iPAP of 15 cm and PEEP/ePAP of 5 cm provide a pressure support of 10 cm H_2O. This configuration supports breathing by reducing the workload on respiratory muscles, improving oxygenation, and stabilizing the airways. iPAP (Inspiratory Positive Airway Pressure) of 15 cm is a higher pressure applied during inhalation to facilitate air intake, increase tidal volume, and reduce breathing effort. A PEEP (or ePAP) of 5 cm is a lower pressure level that is maintained during exhalation to prevent airway collapse, reduce intrinsic PEEP, and enhance oxygenation. We used such ventilatory support in this patient who had infections, respiratory failure, and hypoventilation syndrome due to neuromuscular disorders (quadriplegia is a risk factor for central sleep apnea). During NIV treatment, the patient's level of consciousness and alertness remained elevated (Glasgow Coma Scale score of 15 until discharge), with a constant respiratory rate and high oxygen saturation throughout the hospital stay. Blood gas analysis also showed a decrease in the hypercapnia. Furthermore, a significant finding for us (also from a rehabilitation perspective) was reduced use of accessory muscles. This reduced use of the sternocleidomastoid and scalene muscles for inspiratory activity, which was also observable during physical medicine and rehabilitation consultations, led to further positive results thanks to diaphragmatic exercises and the synergy of NIV and the motor program, which encouraged us not to modify the device's inspiratory support parameters. Once blood gas values improved, treatment continued with oxygen therapy in PCV (Pressure-Controlled Ventilation) mode, a non-invasive mechanical ventilation technique used to support the breathing of patients with respiratory failure by ensuring a preset airway pressure with low flows (2 liters per minute).

Overall, the IRP not only optimized respiratory and musculoskeletal management but also provided a structured framework for maintaining functional stability, thereby reducing the risk of additional medical complications. This multidisciplinary approach highlights the essential role of early and integrated rehabilitation in the comprehensive care of patients with severe neurological and systemic comorbidities. There was an improvement in spasticity, especially in the lower limbs (MAS 3).

The patient was discharged after approximately 1.5 months of hospitalization. Inflammatory markers had significantly decreased (CRP 249.3 mg/dL in the ED, CRP 35 mg/dL on discharge), and hemoglobin levels had improved compared to admission (9.6 g/dL vs. 7.4 g/dL, normochromic normocytic anemia), as had the severe caloric-protein malnutrition profile at admission (an absolute weight gain of 2 kg and total protein levels within the normal range). Vital signs on admission to the ED: BT 37.1°C, BP 95/58 mmHg, HR 66 bpm, SpO_2 98%, vital signs on discharge: BT 36°C, BP 130/80 mmHg, HR 87 bpm, SpO_2 100%, eupneic patient on room air currently connected to the ventilator, breathing spontaneously. The Glasgow Coma Scale remained maximal. Normal CFU on control bronchovasal examination.

At discharge, due to this frailty, he was transferred to the residential social-assistance health facility from which he had originally been taken to the ER. This ensured an adequate prosecution of the assistance for the overall clinical and functional status of the patient.

Discussion. Lower respiratory tract infections (LRIs) are a major cause of hospitalization for children and adolescents with a tracheostomy. In a recent retrospective study, Acinetobater Baumannii was found to be the infectious agent most commonly involved in these infections [9]. In the presented patient, the presence of the respiratory “prosthesis” certainly represented the main risk factor for what subsequently occurred, as demonstrated in a recent meta-analysis [10], as the tracheostomy favors micro inhalations of the oropharyngeal contents, the reduction of the defenses of the upper airways, and the formation of a biofilm with consequent increase in the bacterial load [11, 12]. Literature is currently lacking reports specifically investigating the effects of NIV and motor-respiratory re-education in patients with spastic quadriplegia secondary to cerebrovascular injury; major evidence can be drawn from partially analogous conditions (e.g., neuromuscular disorders, COPD, and other neurological conditions associated with respiratory muscle weakness) to provide the most comprehensive interpretive framework currently available for this underrepresented clinical population. The choice about the NIV application in this case has been based on the most recent evidence [13]. NIV can ensure protective lung ventilation by providing diaphragmatic ventilation that other types of oxygen therapy and mechanical ventilation do not have [14]. In turn, there is experience with patients with severe and very severe chronic obstructive pulmonary disease in which the use of NIV can enhance the benefits of a respiratory re-educational program, allowing patients to perform lung and muscle recruitment exercises at higher intensities and therefore improving patient performance [15]. A recent Cochrane meta-analysis has failed to clarify all doubts on the matter [16]. While respiratory re-education has demonstrated potential benefits in recent history, evidence regarding its impact on crucial outcomes in adults with pneumonia remains inconclusive [17]. Specifically, its effects on mortality, cure rates, and the duration of hospitalization, fever, intensive care unit stays, and mechanical ventilation have not been definitively established. In a trial by Plowman et al. in patients with amyotrophic lateral sclerosis treated with NIV ventilation, a training program of inspiratory and expiratory respiratory force was studied to improve airway clearance at least in the initial stages of the disease. The results obtained, however, need further confirmation [18]. Even more complex is the study of the impact of respiratory re-education on patients who are treated with NIV, experience a pneumonic episode, and suffer from quadriplegia [19]. In patients with stroke and motor disability with hemiplegia, there is certainly a motor impairment of the respiratory muscles. Therefore, NIV and targeted therapeutic exercise can play a synergistic role [20]. In fact, enhanced motor function improved respiration, and re-educational programs should prioritize diaphragm function to improve overall outcomes. Non-ventilatory factors also affect the efficacy of NIV, and various solutions have been described and must be implemented, including cough-assist techniques, control of excess salivation, and nutrition [21]. Certainly, from the data that have emerged so far, early mobilization produces positive effects in contrasting the weakness of patients who spend long periods in ICUs [22, 23]. A study by Ntoumenopoulos G et al. on 60 patients also demonstrated an even preventive effect of physiotherapy on the onset of ventilator-associated pneumonia [24]. Effective pulmonary re-education necessitates a multifaceted approach. Key considerations include patient selection to carefully identify suitable candidates, and individualized assessment that considers each patient’s unique needs and limitations. It would also be paramount conditions and tailor interventions accordingly. There are not many targeted studies in the literature on specific respiratory rehabilitation programs followed, so it is complex today to try to implement a standardized treatment, especially when the patient has numerous disabling pathologies, as in our case. The recent experience of El-Moatasem AM et al., for example, with intrathoracic oscillations, involved younger patients than the one reported here [25]. Respiratory re-education is widely prescribed to assist the clearance of airway secretions in people with cystic fibrosis, too. Positive expiratory pressure devices provide back pressure to the airways during expiration. This may improve clearance by building up gas behind mucus via collateral ventilation and by temporarily increasing functional residual capacity, with very encouraging results from a meta-analysis on many patients affected [26]. It remains uncertain whether these findings apply to older patients with severe motor impairments affecting all four limbs and receiving mechanical ventilatory support. To ascertain this, a study should be designed to evaluate the incidence of pneumonias and pulmonary exacerbations as primary outcomes.

This case offered several lessons. First, it demonstrated that in patients with spastic quadriplegia on long-term mechanical ventilation, infectious stability is not merely a pharmacological achievement: it requires the active, concurrent contribution of a structured IRP targeting airway clearance, respiratory muscle function, and postural management. The synergy between NIV optimization and the IRP, particularly the use of mechanical insufflation-exsufflation, lung volume recruitment maneuvers, and progressive postural adjustments, proved an effective factor in preventing further infectious episodes during hospitalization. Second, and perhaps most importantly, it underscored that the physiatrist’s role in critical and post-critical settings is not ancillary but central: early involvement in the multidisciplinary team enabled a personalized, adaptive rehabilitation strategy that contributed directly to the patient’s clinical stabilization and safe discharge. Future case series and prospective studies should build on experiences such as this one to define minimum rehabilitation standards for patients with severe neurological disability and recurrent respiratory complications.

2.1 Ethics Statement

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was waived, considering the inherent retrospective and observational nature of the case report study design.

3. Conclusions

The physiatrist can set up an IRP with various functional re-educational programs for respiratory assistance, through manual or mechanical techniques to facilitate the clearance of secretions, hyperinflation via ventilator, and manual thoracic techniques. There are positive expiratory pressure devices that can facilitate mucociliary clearing. Through the use of PEEP, it is possible to increase lung volume, recovering areas of atelectatic lung. For this purpose, the use of NIV in these patients appears to be highly beneficial. Therefore, these effects can also be used as an outcome measure in respiratory re-educational treatments or the NIV parameters can be set dynamically in order to ensure progressive training of the respiratory muscles in patients followed by both the physiatrist and the pulmonologist in a constructive exchange. There is a lack of data in the literature that could lead to the use of standardized protocols because the studies examined are very heterogeneous. Therefore, study protocols are needed that clearly highlight all outcome measures.

The clinical case taken into account, although very complex, highlights the need to continue on the path undertaken and intensify studies in patients co-affected by neurological and respiratory pathology to ensure that they receive the best possible treatment based on evidence.

Abbreviations

AVM	Arteriovenous Malformation
CRP	C-Reactive Protein
CT	Computed Tomography
PRM	Physical and Rehabilitation Medicine
ER	Emergency Room
NIV	Non-Invasive Ventilation
MRSA	Methicillin-Resistant Staphylococcus Aureus
PEG	Percutaneous Gastrostomy
ICU	Intensive Care Unit
PICC	Peripherally Inserted Central Catheter
DEU	Emergency and Urgency Department
BAL	Bronchoalveolar Lavage Fluid
iPAP	Inspiratory Positive Airway Pressure
PEEP	Positive End-Expiratory Pressure
BiPAP ventilation	Bilevel Positive Airway Pressure ventilation
PCV	Pressure Controlled Ventilation
MAS	Modified Ashworth Scale
PCR	Plantar Cutaneous Reflex
LRIs	Lower Respiratory Tract Infections

Author Contributions

Conceptualization, V.M.M. and N.M.; methodology, N.M.; investigation, V.M.M., A.S. and C.L.; writing—original draft preparation, V.M.M., A.S. and C.L.; writing—review and editing, N.M. and C.F.; visualization, V.M.M.; supervision, C.F. All authors have read and agreed to the published version of the manuscript.

Competing Interests

The authors have declared that no competing interests exist.

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