Effects of Exercise Training on Forced Expiratory Flow in Individuals with Spinal Cord Injury with Prone Positioning: A Serial Case Report

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Abstract: Two Spinal Cord Injury (SCI) patients with the diagnosis of thoracic level Asia Impairment Scale (AIS) A chronic phase were re-hospitalized. A 23-year-old male with accompanying problem of multiple pressure sores, deep vein thrombosis (DVT), and anemia; and a 13-year-old-female with accompanying problem of pressure sores and anemia. Debridement and flap surgeries were performed in treating existing pressure sores. Six weeks of tailored-made rehabilitation program were given including the prone positioning in the midst of the ongoing program. Each subject completed peak cough flow (PCF), peak flow rate (PFR), and Spinal Cord independence Measure (SCIM) for respiratory function-interview based. Re-admitted chronic SCI patients had exercise tolerance which put them at risk of pulmonary complications. A good exercise tolerance will support the respiratory function by increasing vital capacity (VC), thus enhancing cough ability as a protection of respiratory system. Prone position also has certain advantages that can still be conducted by SCI patients in preserving respiratory capacity. Conclusions: Good exercise tolerance along with good airway cleansing technique is an effective way to prevent complications of the respiratory system in chronic SCI patients who must be in a prone position for a certain period of time.

1 CASE DIAGNOSIS

Case I, A 13-year-old female patient with chronic phase of high paraplegia (T3) SCI is being admitted to hospital due to multiple pressure sores and anemia. Case II, H, 23-year-old male, suffered from chronic SCI of lower thoracis (T9) re-admitted to hospital due to DVT, multiple pressure sores, and anemia. Both patients needed to be maintained in prone position due to debridement and flap surgery performed in treating existing multiple pressure sores while rehabilitation program remains continued.

2 CASE DESCRIPTION

Case I, A 13-year-old female patient with chronic phase of high paraplegia (T3) SCI is being admitted to hospital due to multiple pressure sores and anemia, due to limited activity for past 1.5 years. Patient had no history of pulmonary infection before admitted to hospital. For the physical examination, she has inadequate cough ability, and was found to be low endurance cardiorespiratory due to inability to maintain active upright position. One week after admitted to hospital she had worsening anemia which was thought to be due to worsening pressure sores. She was then underwent a debridement and flap surgery procedure. She had been doing active rehabilitation consist of proper positioning, breathing exercise with chest splinting, advanced wheeling to increase cardiorespiratory endurance,

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and transfer techniques prior to surgery, but she was unable to continue training due to worsening anemia for the next 2 weeks. Blood cultures and wound swabs were carried out, and she had been treated with specific antibiotics. She was then scheduled for debridement and flap surgery. After procedures, she was ordered to be in prone position for at least 2 weeks. While in the prone position, she can only do expiratory muscle training using Positive Expiratory Pressure (PEP) device. PCF and PFR measurements were taken prior to the exercise (baseline), before the prone position (P1), and after the prone position (P2). (table 1).

Case II, H, 23-year-old male, suffered from chronic SCI of lower thoracis (T9) re-admitted to hospital due to DVT, multiple pressure sores, and anemia. Patient had no previous history of pulmonary infections. After medically stable, he was given training to improve cardiorespiratory endurance. He was also scheduled for debridement and flap surgery, and was ordered to be in prone position for at least 2 weeks. Before being in a prone position, the patient had gone through an upper extremity strengthening exercise program and was capable of wheeling advanced. PCF and PFR measurements were taken prior to the exercise (baseline), before the prone position (P1), and after the prone position (P2). (table 1).

3 RESULTS

Exercises provided during the 6 weeks of hospital treatment include proper positioning, breathing exercise technique, respiratory muscles training, upper limb strengthening include body weight lifting exercise, aerobic exercise to increase cardiorespiratory endurance, and transfer technique. All exercises were tailored-made to patient's needs.

Case I, patient had done very well for the first two weeks, but entering the third week, patient had fever and anemia, her pressure sore started to build a tunnel around the first wound and actively bleed, thus she had to stop exercising for a while. On the fourth week, she had to do the debridement and flap surgery that required prone position for at least 2 weeks after the operation was performed. At that time, she still hadn't been able to lift the body using the upper limbs strength, thus she only did exercises using positive expiratory pressure (PEP) device started with 30% dose of maximal expiratory pressure (MEP) with a gradual increase. The results obtained were increase in PCF and PFR at week 4 (P1) and at week 6 (P2) . No increase in SCIM score for management sphincter and respiratory (table 2).

In case II, patient had already had a good exercise capacity before starting the regiments. the patient was able to do exercise regimen in the first 4 weeks of treatment in the form of strengthening the muscles of the upper limbs and cardiorespiratory endurance, so that after debridement and flap surgery on the fifth week and the patient is required to be in a prone position, he was able to continue the strengthening exercise regimen that has been done before, although he has not been able to continue aerobic exercise due to limited space. The results showed, the patient had an increase in PCF and PFR in the fourth week before the prone position (P1), and at the end of the sixth week after the prone position lasted for 2 weeks (table 1). No increase in SCIM score for management sphincter and respiratory (table 2).

Table 1: Results of Peak Flow Meter (PFM) at baseline, before prone positioning (P1), after prone positioning (P2).

	Baseline (l/m)		P1 (l/m)		P2 (l/m)	
	PCF	PFR	PCF	PFR	PCF	PFR
Case I	110	130	140	160	150	170
Case II	350	360	420	400	480	460

Table 2: Results of Spinal Cord Independence Measure for sphincter management – bowel at baseline, and post treatment (S1 (S0)).

Subject	SCIM	
	Baseline (S0)	Post (S1)
Case I	10	10
Case II	8	8

4 DISCUSSION

Pulmonary complications remain a major cause of morbidity and mortality in SCI population. Injury to the upper and lower thoracic cord may disrupts function of the intercostal muscles, accessory respiratory muscles, and abdominal muscles. Patients may have ineffective cough and difficulty clearing secretions which in turn predispose to mucus retention, atelectasis and pulmonary infections, and ultimately to significant morbidity and mortality.

Ability to generate adequate cough is important to protect respiratory functions in SCI patients. Peak Cough Flow is the maximum flow recorded immediately following opening of the glottis. This leads to the rapid expulsive phase of a cough, resulting from the sudden release of high intrapleural and thoraco-abdominal pressures. To achieve a functional PCF (to expectorate secretions) requires at least 50% of vital capacity and sufficient thoraco-abdominal pressure (in excess of 100 cmH_2O) to produce at least a flow of 270 l/m. In order to move any mucus within the airways, PCF must exceed at least 160l/m. Combination with sufficient expiratory muscle strength is required to generate the required thoraco-abdominal pressures (Anderson, 2005).

Both patients had been through rehabilitation program for six weeks. The results corresponding to the PCF and PFR before and after rehabilitation program are described in Table 1. In case I, patient experienced an increase in PCF and PFR during active rehabilitation following training to improve cardiorespiratory endurance, this is in line with research by Houtte et al and Moro et al which confirmed that respiratory muscle training tended to improve expiratory muscle strength, vital capacity, residual volume, and also increasing ventilation efficiency in subjects with SCI (Moro et al, 2005). She continues to train her expiratory muscles using PEP. In case II, after the prone position is applied, the patient is still able to do strengthening exercises on the upper limb in the form of push up and weight training for as long as 30 minutes/day, 5 days a week. Patient wasn't given training using PEP because he have good PCF and PFR baselines (more than 270 l/m).

Pulmonary function in SCI is mainly limited by the weakness of respiratory muscles, therefore, training of the remaining respiratory muscles in SCI and the use of compensatory respiratory mechanism, such as m. pectorals function for expiration may improve pulmonary function (Houtte et al, 2006). Prone position can also give benefit to respiratory function by improving lung parenchyma mechanics and arterial oxygenation, attenuating lung inflation gradient, eliminating lung compression by the heart, and make regional alveolar ventilation become more homogenous resulting in reduction of alveolar atelectasis and hyperinflation. Decreased atelectasis and more uniform inflation may result in more homogenous and increased average alveolar septal tension (Metzelopoulos et al, 2005). The gravitational gradient of intrapleural pressure is suggested to be less in prone posture than supine. Thus the gravitational distribution of ventilation is expected to be more uniform prone, potentially affecting regional ventilation-perfusion ratio (Henderson et al, 2014).

In the supine position, there is predominance of ventilation in the ventral area of the lung and perfusion in the dorsal area of the lung, resulting in a heterogeneous ventilation-perfusion ratio in various lung areas. This is due to the influence of gravity on the solid mass of the lung, pulmonary vascularization and the transpulmonary gradient associated with alveolar size. In contrast to the pronation position, the solid lung mass and blood flow are distributed to the ventral by the influence of gravity, resulting in a more homogeneous ventilation-perfusion ratio in the ventral and dorsal areas so as to improve gas exchange and increase oxygenation (Glenny et al, 2011).

Patients with prone positioning experience a more even distribution of tidal volume because the vertical gradient of pleural pressure becomes more negative in the dorsal portion of the lung. In the pronation position, the pressure from the heart and the abdominal cavity also decreases so that the lung volume in the dorso-caudal region increases (Glenny et al, 2011).

In the supine position, the size of the alveolar will become more heterogeneous, where the size of the alveolar from the non-dependent (ventral) to the dependent (dorsal) area of the lung will become smaller, thereby increasing the risk of atelectasis in the lung-dependent area. In contrast to the pronation position, alveolar size in the lung dependent area will be greater due to the Slingky effect on lung tissue, thus, alveolar size will become more homogeneous while reducing the risk of atelectasis (figure 1) (Hopkins et al, 2015).

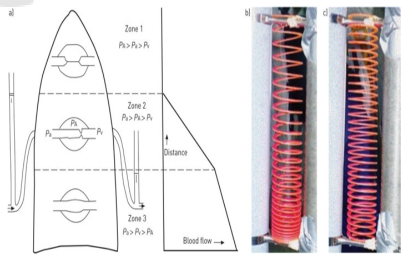

Figure 1: Slinky effect.

5 CONCLUSIONS

Good exercise tolerance is required to maintain activities level needed by SCI patients along with good airway cleansing technique to prevent complications of the respiratory system in chronic SCI patients.

Prone position turns out to have benefits for both SCI patients in Case I and Case II. In Case I, there is no episodes respiratory tract infections during treatment in the hospital despite having a minimum PCF and PFR limits to be able to do good airway clearance. In Case II, patient was still able to carry out exercise activities while in the prone position, and showed increasing PCF and PFR which are the reflection of improving airway clearance ability.

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