Government of Western Australia
Department of Health

Respiratory Function following Spinal Cord Injury

A Resource for Health Service Providers

WA State Spinal Injury Unit

Version 1 November 2013
Review Date November 2016

This document has been developed to provide health service providers with a sound understanding of the impact of Spinal Cord Injury (SCI) on respiratory function, both in the acute and long-term stages following injury

Key points

- Respiratory function following a SCI is primarily determined by the extent and level of neurological injury, due to the partial or complete paralysis of respiratory muscles innervated below the neurological level of injury.
- There are 4 main muscle groups involved in respiration: Diaphragm (Phrenic Nerve Cervical 3-5), Accessory muscles of neck and shoulder girdle (C1-C8), Intercostals (T1-T12) and Abdominals (T6 -T12).
- Alterations in respiratory function following SCI include:
    - Reduction in lung capacity
    - Impaired ability to cough
    - Altered breathing pattern
    - Imbalance in Autonomic Nervous System following a SCI above the level of T6, with relative bronchoconstriction (airway narrowing) and increased secretion production
    - Chronic secondary changes including reduction in lung and chest wall compliance (flexibility)
- There is a high incidence of respiratory complications following SCI, which are one of the leading causes of hospital readmission and mortality. Common respiratory complications include atelectasis (segmental lung collapse), pneumonia and respiratory failure.
- Measures of respiratory function do not return to pre-injury levels, and there is a degree of ongoing impairment of respiratory function that is life-long
- Vital Capacity assessment is a reliable measure to monitor respiratory function and stability, both in the acute and long-term stages following SCI.
- Risk factors for respiratory complications include:
    - Higher neurological level of SCI
    - Older age (>50 years) and increased time since initial injury
    - Recent hospital admission or prolonged bed rest
    - Co-morbidities such as respiratory disorders (eg. asthma, COPD, bronchiectasis, bronchitis), smoking history, obesity, severe postural deformity (e.g. Scoliosis, kyphosis)
- A person with a SCI will find it easier to breath when laying flat. Never sit up a SCI patient who is in respiratory distress. An abdominal binder should be used in the acute setting.
- Individuals with a SCI should be regularly reviewed, with routine screening of respiratory function.
- Education to promote long-term self-management is essential to maintain respiratory function and prevent complications.

Introduction

Respiratory function following SCI is primarily determined by the level and severity of the neurological injury, as a result of the partial or complete paralysis of respiratory muscles. The alterations in respiratory function that occur following SCI can be summarised by the following:

- Reduction in lung capacity
- Reduction in ability to generate high expiratory flow rates make coughing and clearing secretion ineffective
- Heightened risk of respiratory muscle fatigue and respiratory failure due to reduction in respiratory reserve capacity
- Altered respiratory mechanics and breathing pattern
- Autonomic nervous system dysfunction with a relative increase in bronchospasm and secretion production in SCI above the level of T6 [3-4]

[1-2]

In the acute stages following SCI, individuals are at their most vulnerable in terms of respiratory status. However, there is a persisting degree of respiratory system dysfunction throughout the lifespan [5]. This significantly increases the risk of developing respiratory complications, most commonly atelectasis (segmental lung collapse), respiratory tract infection and respiratory failure lifelong[1,6,7]. Respiratory complications have been identified as a leading cause of hospital readmission [8-9], as well as acute and long-term mortality following SCI [6,9,10]. The incidence of respiratory complications in the acute stages following SCI is reported to be as high as 80% [6]. Furthermore, increased time since injury has been consistently associated with a higher incidence of respiratory complications [11-12].

Effective respiratory management, and self-management education, are therefore essential goals of acute and long-term care.

Anatomy and Physiology

Nervous System Control of Respiration

The respiratory system, is controlled by both voluntary and involuntary mechanisms. The Parasympathetic Nervous System (PNS) acts via cranial nerves on smooth muscle of the airways. It is responsible for the production of secretions (mouth, nose and lungs) and narrowing of airway diameter (bronchoconstriction). The Sympathetic Nervous System (SNS) acts via spinal nerves in the upper thoracic spine (T1-T6) to increase airway diameter (bronchodilation).

Following SCI above the level of T6 an imbalance in these actions is evident due to an unopposed PNS activity. This results in relative bronchoconstriction and increased production of secretions within the airways, which further compromises respiratory function.

[2-4]

Muscles of Respiration

There are four primary muscle groups that are involved in respiration.

Diaphragm (Phrenic Nerve C_3-C_8)
The diaphragm is the primary muscle responsible for inspiration (breathing in). A dome-shaped muscle that sits at the bottom of the lungs that contracts and lowers to draw air into the lungs. It then relaxes during expiration (breathing out).

Individuals with a complete SCI at or above the level of C3 are likely to require mechanical ventilation support due to the loss of diaphragm function.

The Accessory Muscles
The accessory muscles include muscles of the neck and shoulder girdle, such as the Scalenes (C3-C8), Sternocleidomastoid (Cranial Nerve XI) and the Pectorals (C5-T1). These muscles assist with expansion of the upper ribcage during inspiration.

Intercostals (T_1 – T_{11})
The intercostals are 2 groups of small muscles that are located between each of the ribs. The external intercostals assist with inspiration by elevating the rib cage during lung expansion. Internal intercostals assist with forced expiration i.e. coughing and sneezing.

Abdominals (T_6 – T_{12})
Abdominal muscle contraction increases the intra-abdominal pressure. They are the primary muscles involved in forced expiratory maneouveurs i.e coughing. They also act to support the abdominal contents and maintain the optimal position of the diaphragm when the body is upright making breathing easier for SCI individuals when lying flat [13-15].

Respiratory Function following SCI

Respiratory function following SCI, and the risk of developing acute respiratory complications, are influenced by:

- The neurological level of injury [6,11,16-18]
- Motor complete SCI (ASIA Impairment Scale A or B) is at a higher risk than motor incomplete SCI (ASIA Impairment Scale C or D) [11]
- Individual factors such as age (>50 years), high body mass index (BMI) and smoking history [11,12,17]
- Pre-existing co-morbidities (eg. Asthma, COPD) [11,12,17]
- Time since acute injury i.e. Increased time since injury = increased risk [11,12]
- Mechanism of injury and other associated injuries i.e. associated chest injuries and high risk of aspiration in water-based injuries (acute)
- Recent hospitalisation or period of prolonged immobilization/bedrest [19,21]
- Severe postural deformity eg. Scoliosis, kyphosis [19,21]

Table 1 provides a summary of the impact of SCI on lung capacity, and the clinical implication.

Measure	Definition	Clinical Implications post SCI
Vital Capacity (VC)	Volume of air breathed out after a maximal inspiration	Reduced Recommended clinical measure to monitor respiratory function and stability, in acute and long-term stages following SCI [7,19-21] Can be as low as 53% of the individual's normal value in a high level tetraplegic.
Total Lung Capacity (TLC)	The total volume of air that it is in the lungs after a maximal inspiration	Reduced VC reflects total lung capacity, as it is a clinical measure of inspiratory lung capacity
Tidal Volume (V_t)	Volume of air breathed in and out during a normal breath at rest	Mildly reduced, compensated for with increased respiratory rate Tidal breathing requires a greater percentage of TLC
Inspiratory Reserve Volume	Additional volume of air that can be breathed in after taking a normal ('tidal') breath in	Reduced
Peak Expiratory Flow Rate (PEFR)	Maximum flow rate of air that can be expired after a maximal breath in	Reduced Also results in a reduction in peak cough flow rate limiting cough effectiveness Can be as low as 42% of the individuals normal value in a high level tetraplegic.
Forced Expiratory Volume in 1 Second (FEV_1)	Volume of air that can be forcefully expired in the first second after a maximal inspiration	Reduced Correlates with effectiveness of cough Can be as low as 49% of the individual's normal value in a high level tetraplegic.

Table 1 [1,7,11]

Measures of lung capacity have been shown to be predictive of the risk of developing a respiratory tract infection following a SCI [8]. They also impact on voice projection and volume, as well as respiratory capacity during physical activity.

Lung capacity is also influenced by posture. Following a SCI above the level of T12, the abdominal muscles no longer support the abdominal contents, which are displaced forwards and downwards by gravity when the body is in an upright position. Lung capacity is therefore greatest when laying flat, and work of breathing is higher when in a upright posture [1,13-15].

NEVER position an individual with SCI in the sitting position when in respiratory distress. Lying flat will assist respiratory function and decrease work of breathing.

There a number of other secondary factors which impact or reduce upon respiratory function, in the acute and long-term stages following injury [1, 7]:

- Prolonged period of bedrest and relative immobilization [1, 7]
- Effect of pain and sedation associated with pain medication [1, 7]
- Abdominal distension secondary to paralytic ileus (acute) or constipation, which hinder diaphragmatic movement [1, 7]
- Reduced pulmonary compliance, or increased stiffness of lung tissues. Compliance can be reduced by up to 30% in individuals with Tetraplegia[1, 7]
- Reduced chest wall compliance, or increased stiffness of the rib cage as a result of reduced chest wall expansion and limited physical mobility [1, 7]
- Musculoskeletal changes, for example scoliosis or kyphosis, may reduce ribcage expansion [19,21]
- The presence of Obstructive Sleep Apnoea (OSA), which is reported to be as high as 40 [7] – 60% in individuals with Tetraplegia [19,21]

Respiratory Assessment

Respiratory assessment and management for individuals with SCI is not dissimilar to other populations, however some additional assessments and intervention are advocated. Assessment will be required when the individual is acutely unwell but is also should be considered routinely to prevent respiratory compromise.

Acute Assessment

- Vital Capacity (VC). Bedside spirometry has been demonstrated to reliably correlate with full pulmonary function testing [22].
- PEFR or FEV_1 provide additional spirometry measures to evaluate respiratory function, in particular the effectiveness of cough. Peak cough flow rates in able-bodied individuals range between 6-20 litres per second (L/sec) [1]. SCI individuals who have a VC less than 1.5 litres, and who are unable to generate peak expiratory flow rate greater than 4.5L/sec, will be unable to cope during times of acute respiratory compromise [1]. Cough can also be assessed clinically by evaluating the strength and effectiveness at the bedside.
- Regular monitoring of Arterial Blood Gases (ABGs) for early signs of respiratory failure, which is indicated by increasing Carbon Dioxide (PaCO2) and deteriorating Oxygen (PaO2) levels [7].

Routine Assessment

- Standard subjective respiratory assessment
    - Shortness of breath, subjective report of respiratory distress or increased work of breathing
    - Incidence of respiratory infections
    - Ability to clear secretions, information on volume and tenacity of secretions
    - Any episodes of blood in sputum or weight loss recently
    - Previous hospital admissions
- SpO2, RR, Auscultation, Cough
- Cardiovascular observations including HR, BP, Temperature

- Radiology i.e. Chest X-Ray
- Spirometry, specifically VC and FEV_1 / peak expiratory flow rate
- Assessment for possible Obstructive Sleep Apnoea
    - Snoring, or apnoeic episodes overnight
    - Excessive fatigue or sleepiness during the day
    - Early morning headache
    - Difficulty concentrating and focussing during the day

Respiratory Management

Strategies to Improve Cough

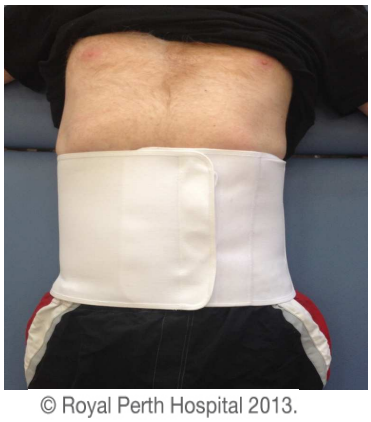
An effective cough requires a large inspiratory volume followed by an expulsive expiration produced by the internal intercostals and abdominal muscles (T1-T12) [1]. Peak expiratory flow rates during cough can be improved by providing manual assistance, either by a carer or by the individual themselves. A ***manually assisted cough*** increases peak expiratory flow rates during cough [23] by up to seven times what the individual is able to generate themselves [1]. The technique involves using the hands to apply a rapid and forceful pressure to the ribcage or abdominal wall timed with the individuals cough and to be effective may require one or two people to assist. **As this is a forceful technique, it is vital to clear any possible contraindications such as the presence of IVC filters, acute abdominal or chest injuries**. Where possible, individuals are taught techniques to perform a self-assisted cough.

Clearance from Spinal Team prior to implementing this should be sought

- The carer should feel for the base of the sternum (breast bone) and the belly button.
- Place the heel of the hand midway between the two points.
- As the person is about to cough, the carer should thrust the heel of the hand firmly inwards and upwards, towards the diaphragm

Abdominal Binder

The use of an abdominal binder will assist in supporting abdominal contents and the diaphragm when in an upright position. Abdominal binders have been shown to increase V_t by 16-28% [5,7], and significantly improve VC when upright [13-15]. In the acute stages following a SCI, it is recommended that an abdominal binder be worn when sitting upright. Individuals are usually able to manage without an abdominal binder in the long-term, however it can be considered in times of respiratory compromise.



General Considerations

To support people with SCI to effectively manage their own respiratory health the following is recommended

- Encourage smoking cessation [11-12,17]
- Education regarding early identification of an acute chest infection, including when to seek medical advice
- Education on self-management of respiratory complications such as self-assisted cough, airway clearance techniques and use of postural drainage
- Maintenance of cardiovascular fitness through regular physical activity and exercise
- Maintenance of general health through
    - Healthy diet and maintaining of a healthy weight
    - Avoiding contact with others who may have contagious cold or flu
- Annual health review with GP
- Annual influenza and/or pneumonia vaccinations [7,19,21]

If you are involved in assisting a person with a SCI in the community, and you are concerned about their respiratory function, please refer the individual to a medical practitioner for further advice.

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Useful Resources

An online educational tool from the International Spinal Cord Society contains learning modules directed at each discipline.

- www.elearnsci.org

SCIRE Respiratory Management. The Spinal Cord Injury Rehabilitation Evidence (SCIRE) project is a Canadian research collaboration between scientists, clinicians and consumers. SCIRE reviews, evaluates, and translates existing research knowledge into a clear and concise format to inform health professionals and other stakeholders of best rehabilitation practices following SCI.

- http://www.scireproject.com/sites/default/files/respiratory_management.pdf

Spinal Cord Medicine – Clinical Practice Guidelines Consortium for Spinal Cord Medicine Paralysed Veterans of America March 1998 – Respiratory Management following Spinal Cord Injury: A Clinical Practice Guideline for Healthcare Professionals

Resource for health care professionals developed by NSW State Spinal Cord Injury Service – Health Maintenance for Adults with Spinal Cord Injuries

- http://www.aci.health.nsw.gov.au/__data/assets/pdf_file/0007/155167/sci_health_maintenance.pdf

The NSW Spinal Outreach Service have developed a questionnaire to guide health-care providers to identify new health problems and prompt preventive care activities in the ongoing management of SCI clients living in the community.

- http://www.aci.health.nsw.gov.au/resources/clinician-resources

SpinalHub is a Victorian Health website that provides online information for SCI consumers, including respiratory self-management advice.

- http://www.spinalhub.com.au/how-to-keep-healthy/breathing

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The development of this document has been supported by the TRACS WA

Subacute Learning Fund project funding

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