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Physiological considerations in seating

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Abstract

Physiological changes occur with change of posture.

Seating imposes significant effect on the cardiovascular, respiratory, abdominal, renal and neurological systems.

The presence of severe skeletal deformities can significantly alter the physiological responses of the individual to changes in posture. In the case of severe kyphoscoliosis profound haemodynamic changes may occur. Lung perfusion has been shown to be posture dependent and the imposition of a specific seated position may have profound effects. This may compound existing lung problems for example bronchiectasis, which is not uncommon in these individuals, leading to hypoventilation.

Abdominal compression which can occur with the patient in a flexed position can exacerbate a hiatus hernia, which can be both uncomfortable for the patient and may lead to feeding difficulties. The flexion at the hips of the lower limbs may also lead to problems of renal drainage especially where there is a catheter or other drainage appliance.

Seating significantly affects many neurological reflexes. For example the presence of an extensor pattern can be helped by the adoption of a flexed position. The presence of pain can also influence the neurological response to a spe•ific position.

Those providing seating systems must consider the physiological effects that occur and compromise between these and the other requirements.

Cardiovascular and respiratory systems

Normal ventilation consists of an equilibrium between air flow through the lungs and perfusion of the lung parenchyma with blood allowing gaseous exchange to occur. Oxygen is removed from the inspired air and carbon dioxide laden air is expired.

In the normal lung, atmospheric oxygen diffuses into the blood and thereafter to cellular mitochondria as the partial pressure of oxygen (pO_2) in the cells is lower than in the blood. If the arterial pO_2 falls, cellular pO_2 will also fall with a consequential rise of tissue pCO_2 (partial pressure of carbon dioxide). The oxygen balance in the body is dependent on both the ventilation and the metabolic demands of the tissues.

In situations where hypoventilation occurs,

a) there is an increase in alveolar and arterial pCO_2

b) there is a reduction in the alveolar, arterial and cellular pO_2

In these circumstances the patient can become hypoxic.

For efficient gas exchange, ventilation and alveolar perfusion must be balanced. Ventilation-perfusion is the ratio of alveolar ventilation over pulmonary blood flow and is used as a measure of ventilation and blood flow changes in various situations. If, for example, ventilation and blood flow are mismatched, then the ventilation-perfusion ratio alters giving an indication of the oxygen and carbon dioxide changes that can be expected, which may have a profound effect on the body.

The lung has been found to have considerable regional differences in gas exchange.

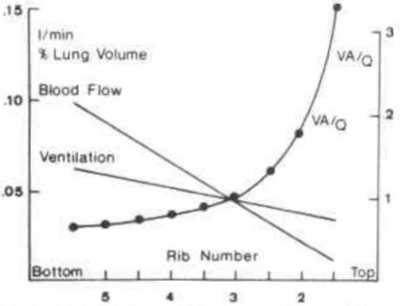

Fig. 1. Distribution of ventilation and blood flow down the upright lung. Ventilation-profusion ratio (VA/Q) decreases down the lung. (From J. B. West, Ventilation: blood flow and gas exchange/3rd edition. — Oxford: Blackwell.)

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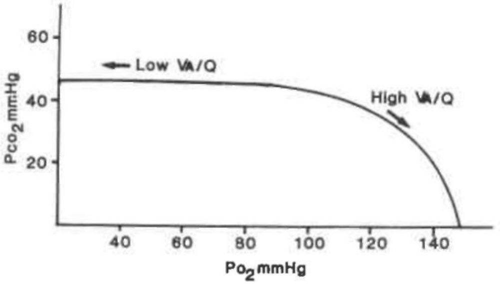

Fig. 2. Oxygen and carbon dioxide diagram, showing that pO_2 and pCO_2 (partial pressure) of all lung units have different ventilation perfusion ratios. (From West, 1987.)

Ventilation increases from the lung apex to the lung base primarily due to the anatomical shape of the lung, there being more lung parenchyma at the base than at the apex. Similarly, pulmonary blood flow increases rapidly from lung apex to lung base due partly to the anatomical shape and also to the hydrostatic and gravitational forces acting on that blood. As a result the ventilation-perfusion ratio is high (>1.0) at the lung apex and low (<1.0) at the lung base (Fig. 1).

This in turn results in different blood gas concentrations in different regions of the lung. At the lung apex where the ventilation-perfusion ratio is high the pO_2 is high while pCO_2 is low. This is because the relative blood flow is low and gaseous exchange can take place at a more leisurely pace. The opposite is true of the lung base (Fig. 2). These regional differences can be quite marked (Fig. 3). In comparison with oxygen, carbon dioxide levels have less regional differences and are more affected by ventilation. This can be seen by reference to the "dissociation curve" of carbon dioxide (Fig. 4). Increase in ventilation raises the carbon dioxide output with high or low ventilation ratios. This contrasts with the oxygen dissociation curve which shows that with low ventilation-perfusion ratios some benefit

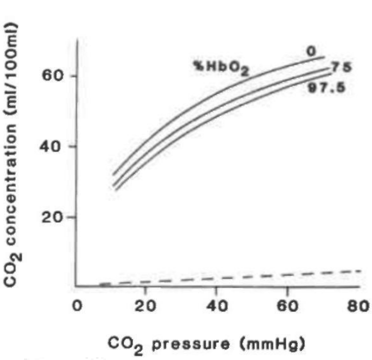

Fig. 4. Carbon dioxide dissociation curve for blood of different oxygen saturation. Note that oxygenated blood carries less CO_2 for the same pCO_2. (From West, 1985.)

is obtained by increasing the ventilation, but in normal situations ventilation itself has little effect on pO_2 level (Fig. 5).

The regional ventilation of the lung can be demonstrated to vary according to the posture adopted. As described above, ventilation in the standing position increases from lung apex to base whereas in the supine position these differences disappear with apical and basal ventilation being similar. In the lateral position the dependent lung becomes the better ventilated (James, 1976).

In deformed chests, for example kyphoscoliotic chests, the anatomical dead space gains greater importance as does the residual volume. The anatomical dead space is "the volume of respiratory system exclusive of alveoli" (Fig. 6). The deformed chest cannot expand normally and thus lessens the amount of gas exchanged. The effective aveolar ventilation also becomes reduced with less fresh inspired air available for gaseous exchange. In severe deformity, the effective respiration can be reduced dramatically leading to the development of pulmonary emphysema. This is found frequently in kyphoscoliosis (Bergofsky *et al.*, 1959).

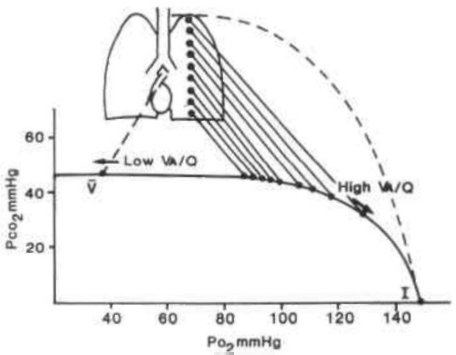

Fig. 3. Regional differences in blood gases in different parts of the lung. (From West, 1987.)

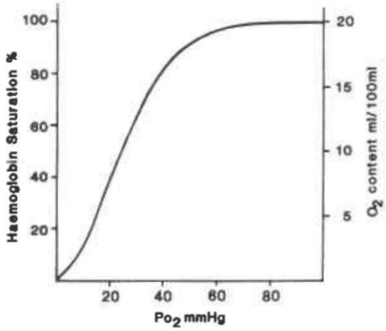

Fig. 5. Oxygen dissociation curve. (Haemoglobin concentration of 14.5g/100ml). (From West, 1987.)

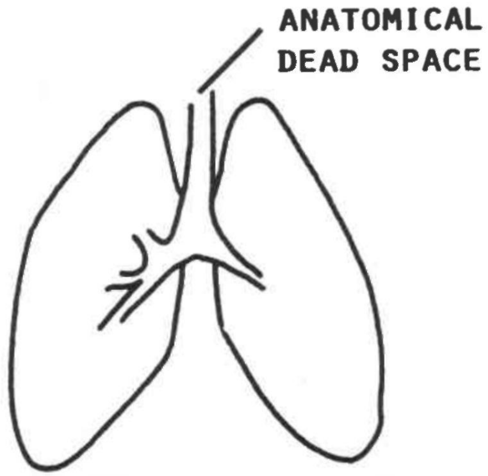

Fig. 6. Anatomical dead space. (The volume of the respiratory system exclusive of the alveoli.)

The deformed chest has, as a consequence of the deformed skeletal shape, a lower than normal lung volume. This can be as much as 63% of the predicted level (James, 1976). The vascular resistance may be raised due to the extra-aveolar vessels becoming narrowed. This results in a linear reduction in blood flow which can be very poor at the apex. When supine the apical blood flow improves with no great change in the basal flow. There may be some change in the antero-posterior plane with posterior (dependant) blood flow exceeding the anterior flow. The changes are explained by the hydrostatic differences of blood in the blood vessels compounded by the increased vascular resistance.

Dollery and his colleagues (1965) reported that some of the changes with regard to the differences in ventilation from apex to the base were not found in ten studied cases of kyphoscoliosis. The ventilation was found to be fairly even although in some older patients ventilation reduction was found in the lower zone. In the younger cases, ventilation was found to be remarkably even, despite gross skeletal deformity (Bake *et al.*, 1972; Dollery *et al.*, 1965). X-rays of kyphoscoliotic chests showed translucent lungs on the concave side suggesting more efficient lungs. The anteroposterior diameter of the lung on the concave side was found to be reduced and thus so also was the lung volume.

No evidence of air entrappment occurs but poorly ventilated spaces have been described. Blood flow is abnormal not due to the kinking in the blood vessels but probably due to the foreshortened chest reducing the total height of the lung tissue. Under-perfusion of lung tissue may however occur and over a period of time, pulmonary vascular resistance may rise and pulmonary hypertension may follow. This may lead to right ventricular loading with the imbalance of ventilation and blood perfusion, with carbon dioxide retention (Bergofsky *et al.*, 1959; James, 1976). The resulting development of chronic hypoventilation may ultimately lead to cor pulmonale. However this complication is rare under the age of 20 (James, 1959). Later, there may develop a reduced ventilation response to carbon dioxide further reducing the efficiency of ventilation.

Increasing scoliosis reduces lung vital capacities. In addition increased rib cage rigidity has been found to occur with increasing age (Caro and Du Bois, 1961) and may be compounded in spinal disease, such as ankylosing spondylosis and kyphoscoliosis. This coupled with the evidence that chest wall compliance rises with age may suggest an increased difficulty with breathing, requiring more effort. Increasing scoliosis has also been shown to result in a fall in the total lung capacity and vital capacity. These changes are significantly greater if a paralytic scoliosis has occurred. Despite increasing kyphoscoliosis with the haemodynamic ventilation changes that follow as deformity progresses, many do not develop problems until later. "Young patients with idiopathic kyphoscoliosis are often symptom free and remain so until middle age when those with severe deformity may become breathless on exertion and develop respiratory, or less often, cardiac failure" (Dollery *et al.*, 1965). During the early years the lungs can cope with the deficiency but as individuals grow older pulmonary resistance increases and some regional hypoventilation may occur and this may be in the scoliotic concavity (Dollery *et al.*, 1965).

There are some for whom respiratory function becomes severely compromised as a result of bronchiectasis. Bronchiectasis is an abnormal and irreversible dilation of the bronchi, usually associated with inflammation and can be caused by the blocking of a bronchus by either mucous or inhaled matter. This often occurs in individuals with severe skeletal deformity and mental deficiency. This plug occludes part of the bronchus trapping air and secretion leading to recurrent infection, ultimately resulting in dilation of the bronchi. Fibrosis of the lung occurs with recurrent infection leading to some arterial-venous shunting. This may be as a result of the haemodynamic changes occurring with enlargement of the bronchial arteries and the development of bronchopulmonary anastomoses. This loss of vital functional lung tissue may be crucial and in those with severe handicap it may be extensive, producing an extraordinarily inefficient lung.

The posture achieved by a seating system can have a direct effect on the cardio-respiratory system. Posture can be seen to affect the physiology of the respiratory system. The maintenance of a good respiratory shape by controlling spinal curvature is in the interests of maintaining a good cardio-respiratory function and long term future (Zorab, 1976). In addition, the seated position may be important in the case of severely handicapped individuals in whom normal physiological swallowing and coughing reflexes may be abnormal. If the individual chokes on food it may become inhaled leading to the development of bronchiectasis which can hasten the development of cardio-respiratory distress.

In the case of paralytic scoliosis, the patient's ability to ventilate is significantly reduced, both due to severe deformity and respiratory muscle weakness. In these circumstances postural problems can lead to respiratory distress requiring extremely careful positioning.

A patient that has been cared for in a supine position will find that postural hypotension may occur if they are suddenly placed in the sitting or standing position. Gradual elevation is therefore needed to counteract this effect, thus allowing the sympathetic nervous system time to readjust to the new position.

The cardio-respiratory system maintains a delicately balanced equilibrium which has considerable reserves. However in the event of skeletal deformity significant changes may occur which can lead to severe cardio-pulmonary disease and premature death. The posture of the individual can be shown to influence directly some of the haemodynamic factors involved and can play an important role in maintaining normal cardio-respiratory integrity.

Abdominal system

The abdomen contains three main physiological systems,

1. Alimentary tract
2. Hepatic system
3. Renal system

Alimentary tract

The alimentary tract is a self regulating digestive system and its function is not significantly affected by posture. Physical inactivity, imposed by a sedentary or wheelchair lifestyle, encourages constipation and the difficulty of transferring can compound this problem making bowel evacuation difficult. Bowel habits with regular evacuation is the norm for fit and healthy adults and disabled individuals require to develop similar regularity if severe

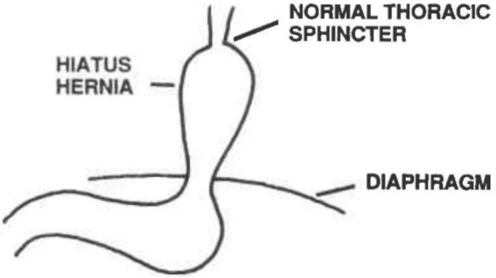

Fig. 7. Herniation of the stomach through the diaphragm resulting in hiatus hernia.

physiological changes are not to occur since chronic constipation, and possibly spurious diarrhoea can be a severe physiologically disturbing problem.

The seated posture itself does not directly affect the digestive system, but reflux oesophagitis may be encouraged by a supine posture. This appears to be common in the severely disabled individual. This is due both to the neuromuscular imbalance and the severe skeletal deformities which may distort the diaphragm, encouraging herniation of the abdominal contents into the thorax (Fig. 7). The supine position encourages reflux of gastric contents into the oesophagus which is extremely uncomfortable and if a chronic problem can lead to peptic ulceration, oesophageal stricture or oesophageal carcinoma. The reflux of gastric contents may lead to aspiration of this material causing either pneumonia or bronchiectasis which, as described above, can have serious consequences. This problem may be helped by careful positioning which may require a compromise.

Ileostomy or colostomy stoma and drainage bags require special consideration. In much the same way as described in constipation, obstruction of these stomas can lead to severe physiological changes. Drainage of these stomas must occur unimpeded and thus the posture adopted is worthy of thought. Ileal conduits which may have been provided to control urinary incontinence require the same consideration since poor drainage can lead to hydronephrosis, recurrent infection and the potential for serious renal damage.

Immobility can lead to obesity exacerbating the problems of transferring in and out of a seat. The very large or very weak require careful positioning if the independence of the individual is to be maintained. In addition the required hip flexion needed to sit can be a problem in very obese people since increased intra-abdominal pressure may compromise the respiratory excursion of the diaphragm, encouraging the development of a hiatus hernia.

Hepatic system

No significant changes appear to occur in this system in relation to seating and therefore no further comment will be made.

Renal system

Incontinence is a major social and hygienic problem. For the wheelchair dependent individual the problems are aggravated by the difficulties of access and transfer into and out of the wheelchair. Inability to transfer may make the incontinence worse since the individual may be aware of the need to micturate but by the time they have got out of the chair it may be too late and involuntary emptying of the bladder may have occurred. Childrens' nappies and incontinence pads can be socially acceptable. These are however bulky, often unhygienic, and present the skin with an environment which encourages bacterial and/or fungal proliferation and, with the moist environment, may lead to skin maceration and breakdown. The efficiency of an intimately fitting seat can be lessened by the bulky incontinence pad which interferes with the seat function and limits its usefulness. The intimacy of the seat and problem of skin breakdown require consideration. These problems can be compounded by anaesthetic skin and pressure loading which may encourage the development of pressure sores.

Those patients with a bladder catheter, urodomes or other incontinence devices require careful positioning. Free drainage of these devices is essential if urinary obstruction is to be avoided. There must not be any "uphill" stretches of conduit as these could compromise bladder drainage leading to potentially damaging urine reflux or hydronephrosis.

Consideration should be given to the individual who has to empty a drainage bag independently since his posture may make this task difficult or impossible thus reducing his level of independence.

Central nervous system

A very significant number of individuals requiring special seating have some form of cerebral inability whether congenital, biochemical or post-natal. The wide range of abnormalities presenting with seating problems are found with considerable variation in clinical findings and difficulties.

The various neurological deficits and ensuing reflexes are discussed by Trefler and Taylor in this supplement.

The problems however that require special seating often require special solutions since the pathology imposes constraints on the ultimate solution. The presence of an extensor pattern of reflexes which appears to be the most frequent can often be overcome by flexion in the hips. However considerable flexion may be required and this in time may encourage the development of permanent flexion contractures, which may or may not be important depending on the person's circumstances.

Flexor patterns may conversely require a more extended position. The presence of primitive reflexes such as the asymmetrical tonic reflex, may require very specific location to reduce them to allow both comfort and function to be achieved.

Involuntary movements present great difficulties for those individuals requiring special seating. These may be athetoid in nature or may present in the form of epilepsy.

Epilepsy imposes its own problems since rapid extraction of the individual from the chair may be necessary. This requires rapid release fasteners if restraints are necessary. Obviously the seat design must avoid potential danger to the occupant if the epilepsy is to be adequately managed.

Pain can severely limit an individual's lifestyle. This pain may be skeletal in origin due to skeletal collapse (e.g. osteoporosis or spinal disease) or pressure on nerves (e.g. osteophyte pressures on spinal nerves) or it may be due to joint damage (e.g. subluxation of the hip). Cutaneous damage as seen in a pressure sore, may lead to severe pain, where the dressings themselves may interfere with the seating system. Positioning must take account of potential pressure points. The severely disabled often find it difficult to explain to those caring for them that they are in pain. The carer in turn however may learn a person's responses to discomfort. Consequently, the carer should be closely involved in the provision of seating since the seating team may not readily be aware of the individual's problems.

The presence of chronic pain can be debilitating and interfere with the quality of life. The position imposed by a seating system may result in the occupant remaining in a predetermined position for many hours. This being so, the seating team must be alert to the possibility of painful postures and these should be avoided whenever possible.

Positioning of an individual in specialised seating can have a profound effect on that individual. The position may affect the tone of the body and the ability of the individual to function independently. Therefore great consideration is needed when supplying a chair. With modern technology a significantly increasing number of individuals have communication aids. The link with the therapist and engineer is crucial if this technology is to be utilised to its maximum potential. Positioning of the individual must take the above into consideration as well as many of the problems mentioned earlier in this text if the person requiring the special seat is to obtain the maximum benefit from the system supplied.

Conclusion

The objectives of seating may involve conflicts with the many medical considerations.

Successful provision of special seating requires the identification of the priorities of these conflicting requirements and subsequent selection of the compromise to achieve a practical solution.

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