

Electrical stimulation of abdominal muscles for control of blood pressure and assisted cough in a C4 level tetraplegic.

PN Taylor, A Tromans*, ID Swain.

Department of Medical Physics and Biomedical Engineering, *The Duke of Cornwall Spinal Treatment Centre, Salisbury District Hospital, Salisbury, Wiltshire SP2 8BJ. Tel. 01722 429 040, Fax. 01722 425 263.

E-mail p.taylor@mpbe-sdh.demon.co.uk Web page www.mpbe-sdh.demon.co.uk.

Abstract - It has been shown by several groups that electrical stimulation can cause autonomic dysreflexia in tetraplegics and high level paraplegics. This effect has been used by a C4 ventilator dependent tetraplegic to raise and maintain blood pressure following postural hypotension, particularly after meals. Additionally the system assists coughing function by stimulation of the abdominal muscles.

Method: A dual channel stimulator was designed that allowed selection and initiation of two predetermined stimulation intensities using a chin controlled joystick. Two sets of 70mm dia electrodes were placed either side of the abdomen. Approximately 80mA, 300 μ s, 40 Hz was required for assisted cough while about 40mA was required for maintenance of blood pressure. After eating the lower level stimulus is self-administered every 3-5min gradually increasing the time between groups of burst to once every hour over 90 minutes.

Results: Following eating a blood pressure of 60 / 45 mmHg was recorded. After five 1 second bursts of stimulation in quick repetition, this was increased to 133 / 92 mmHg. After 2 minutes blood pressure had fallen to 124 / 86 mmHg and to 93 / 66 after a further 4 minutes. The electrical stimulation was then repeated, returning the blood pressure to the previous higher level. Measurement of peak expiratory flow showed an increase from 275 l/min for an unassisted cough to 425 l/min when using the device.

Conclusion: The device is used every day. The user is now independent in coughing function and no longer requires suction or manual assistance. Maintenance of blood pressure has significantly improved his quality of life.

1. Introduction

Autonomic dysreflexia is a common complication of spinal cord injury above the spinal level of T6¹. It manifests as a sudden rise in blood pressure in response to a noxious stimulus below the level of the lesion and, if the stimulus is not removed can lead to headache, cutis, anserina (goose flesh), paresthesias, shivering, flushing and other symptoms. The rise in blood pressure is a

consequence of reflex arterial spasm in response to the stimulation of the sympathetic nervous system. In the intact nervous system baroreceptors in the cerebral vessels, carotid sinuses and aorta detect the hypertension and stimulate a parasympathetic response resulting in vasodilatation, and a fall in heart rate. However, in this group, the signals are blocked by the lesion, the resulting vasodilatation only occurring above the lesion. This is insufficient to return the blood pressure to normal levels. In a similar manner, lowering of blood pressure due to change of posture from lying to a more upright posture can be poorly controlled resulting in postural or orthostatic hypotension.

Autonomic dysreflexia in response to electrical stimulation has been reported by several authors. Ashley² et al. reported rises in blood pressure in response to resistance training using electrical stimulation of the quadriceps muscles. The rise would occur immediately on starting the electrical stimulation but blood pressure returned to normal levels very quickly after stimulation had stopped. More recently, Sampson³ et al. Reported an investigation into the effect of electrical stimulation on blood pressure in C5 – T4 SCI subjects with induced orthostatic hypotension. In this study, repeatable falls in blood pressure was induced using a tilt table. At two separate sessions, the quadriceps and pretibial muscles or the patellae and malleoli were stimulated using a 50 Hz, 250 μ s wave form with currents up to 160 mA. Consistent rises in blood pressure were recorded, overcoming the fall due to induced orthostatic hypotension, whichever stimulation site was used, suggesting that the increase in the muscle pump action on venous return was not a significant factor in the effect. The rise in blood pressure increased with increasing stimulation amplitude but plateaued after 96 mA.

This paper describes a single case study of the use of FES to increase the blood pressure of a C4 ventilator dependent tetraplegic (male, 40 years of age) who was subject to chronic postural hypotension. This was fairly well controlled by the drug Midodrine (midodrine hydrochloride) but low blood pressure remained a problem, particularly after meal times. Additionally the subject controlled his own blood pressure by adjusting his posture by tilting the back and leg rests of his electric

wheel chair, controlled by a chin joystick. The subject was unable to produce a voluntary cough and was dependent on manual assistance and suction to maintain his airways.

It was found that a rise in blood pressure could be induced by stimulation of the common peroneal nerve, quadriceps muscles or the abdominal muscles. By closing his epiglottis, the subject was able to stack up to three breaths. When stimulation of the abdominal muscles was timed to occur just before the end of the third inhalation period, a cough of some force was produced⁴.

2. Method

As the subject was very aware of the status of his blood pressure, it was decided to use a self-administrated system. Two pairs of electrodes were used to stimulate the upper and lower abdomen. An Odstock 2 Channel stimulator (O2CHS)⁵ was used. This device is a foot switch controlled stimulator intended for gait assistance in SCI MS and stroke. In this application its foot switch input was controlled by a spare channel of the wheelchair joystick controller. When the joystick was pushed forward, the stimulator gave a 1 second burst of 300 μ s 40Hz stimulation at amplitudes adjustable between 0 and 80 mA. With a little practice, the subject was able to synchronise the stimulation with epiglottis control and the ventilator's cycle.

The system was used in this form for some months but it soon became apparent that blood pressure was best controlled by fairly frequent but low level bursts of stimulation, lower than that required to produce a cough. The cough function was required less frequently and so the user required assistance to increase the levels of the device when he wanted to cough. It was therefore decided to design a system which allowed user selection of two pre-set levels of stimulation by use of the chin joystick. The new system delivers a low level stimuli if the joystick is flicked for a short time but a larger output is selected if the joystick is pushed forward for three seconds and then releases. An audio warning is given when the cough setting is selected.

3. Assessments

Blood pressure was measured using a calibrated AND digital blood pressure monitor (UA-767). It was measured prior to electrical stimulation, immediately after stimulation and then at two minute intervals until it returned to its previous level.

Peak expiratory flow was measured using a spirometer.

4. Results

Following eating a blood pressure of 60 / 45 mmHg was recorded. After five 1 second bursts of stimulation at an amplitude of approximately 40mA in quick repetition, this was increased to 133 / 92 mmHg. After 2 minutes blood pressure had fallen to 124 / 86 mmHg and to 93 / 66 after a further 4 minutes. The electrical stimulation was then repeated, returning the blood pressure to the previous higher level.

Measurement of peak expiratory flow showed an increase from 275 l/min for an unassisted cough to 425 l/min when using the device. This in the normal range.

The system has been in daily use for 1 year. Typically it is used for regulation of blood pressure after eating. Bursts of stimulation are self-administered every 3-5min immediately after a meal and the period between bursts gradually increased over 90 minutes. At this point the device would typically be used hourly.

The user is now independent in coughing function and no longer requires suction or manual assistance.

5. Discussion

This paper describes a device designed to respond to the specific problems of one individual and it is not clear if it would have application in a wider group. Further work is required to obtain a better understanding of the mechanism of its action. That said, the device has been well accepted by its user and it would appear that by better maintenance of homeostasis, it has contributed to an improved quality of life.

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