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The mobile arm support

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Abstract

The Mobile Arm Support, conceived and researched by Dr. Radulovic, is intended for the use of patients whose arm is afflicted. The support consists of a supporting harness, an articulated splint on which the arm is fixed and a pneumatic system of elevation that counterbalances the weight of the arm. Its originality lies in the use of a splint as a simple lever, supported by a spherical articulation, located as close as possible to the centre of the scapulohumeral joint and linking shoulder and arm movements.

A clinical study involving 18 patients has shown that the support reduces pain, increases ranges of movement of the shoulder and elbow, and increases functional possibilities.

Function

The principle of the Mobile Arm Support (Radulovic 1978) is to support the afflicted member with a movable splint attached to the arm and held in balance by a pneumatic system.

The Mobile Arm Support was not conceived as a passive crutch. On the contrary, its role is to assist whatever active movements the arm is still capable of, without fighting the arm's weight. In order for this to be possible, the muscles of the upper arm must be rated about 2 on the international rating scale; that is when the muscles cannot raise the arm, but can act upon it if its weight is counterbalanced. In this way, if the hand is uninjured but the arm muscles deficient, the hand can be directed in space and thus rendered usable due to the movable support.

Description of the apparatus

The Mobile Arm Support (Fig. 1) consists of three parts, a harness, an articulated splint that supports the arm and a pneumatic system which raises the arm and counterbalances it.

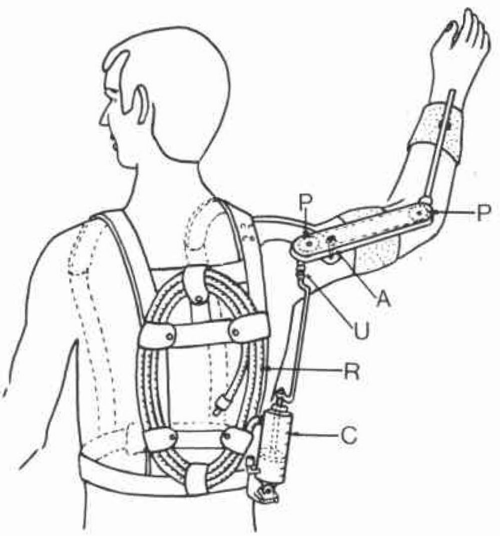

Fig. 1. The splint rests on a supporting spherical articulation (A) attached to the harness. The pneumatic system is composed of a cylinder (C) connected to a reservoir of compressed air (R) made from a simple reinforced pipe. Force is transmitted from the splint by a rod and a universal joint (U). Two pulleys (P) connected by a cable, coordinate the movements of the elbow and shoulder.

1. The harness

The harness is fitted to the trunk and the splint is mounted on it. The framework of the harness is formed from aluminium, the two main parts of which are attached over the shoulders. It is held in position by an adjustable belt and straps.

A spherical articulation is attached to the harness at the level of the shoulders. It is made of hard steel and serves as a support for the arm splint. The support articulation must be located as close as possible to the articular centre of the scapulohumeral joint.

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2. *The supporting splint*

The splint is composed of two metal parts, one for the forearm and the other for the upper arm. The two segments are articulated at the elbow by a uniaxial joint.

The forearm and upper arm of the patient are held in the splint by large self-adhesive straps.

The segment attached to the forearm is made from a cylindrical rod which can turn on its axis, thus permitting pronation and supination of the forearm.

As already mentioned the supporting arm splint is fastened to the harness by a spherical articulation which allows the splint to pivot in any direction.

3. *The pneumatic lifting system*

The principal part of the pneumatic system is a cylinder fixed vertically to the harness at the waist. The cylinder is attached to the harness by a robust universal joint which allows for variations in the orientation of the cylinder.

Inside the cylinder is a movable piston attached to a vertical rod. The rod acts on the posterior part of the supporting arm splint and is attached to the splint by means of a universal joint. This joint plays the role of the origin of force in the lever system that activates the splint (Fig. 2). The pneumatic system is completed by a reservoir of compressed air which is made from a reinforced, coiled pipe 1·5m in length fixed to the back of the harness. The reservoir is connected to the upper part of the cylinder.

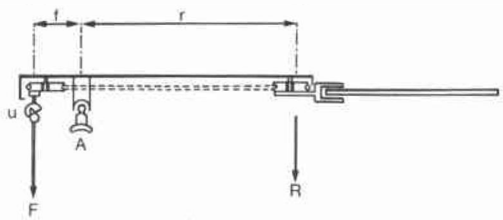

Fig. 2. The splint functions as a simple lever. (A) is the supporting spherical articulation attached to the harness; (R) is the force produced by the weight of the arm and (F) is the force transmitted by the universal joint. The point where the force (F) is applied is fixed eccentrically on the pulley located at the level of the shoulder and is dependent on the movements of the forearm.

Fitting and operation

The harness is fitted to the patient, making sure that the spherical support articulation is placed as close as possible to the articular axis of the scapulohumeral joint. The affected arm is then attached to the splint by the straps.

Air is then pumped into the reservoir by a simple hand pump. When the air pressure in the cylinder is sufficient, it acts on the piston which is forced downwards and draws down the posterior part of the splint. As the posterior part of the splint goes down the anterior part of the splint goes up along with the arm fixed to it as a result of the positioning of the spherical joint.

The pressure in the reservoir must be adapted to each patient so as to equalize the pressure between the piston and the weight of the arm and splint. The pressure required for this purpose usually varies between 1·5 and 3·5 bars.

The reservoir of compressed air and the upper part of the cylinder is a closed system. Once the correct pressure is arrived at, it cannot escape during arm movements. Thus the weight of the arm is balanced.

The one problem that remains to be resolved is how to maintain a correct balance while the arm is stretched or bent. If the elbow is stretched out, the arm's centre of gravity moves away from the shoulder thus adding to the lever arm of the resistance (R). The opposite result is produced if the elbow is bent, the lever arm of the resistance diminishes. Under these conditions it is necessary to vary the piston force, making it proportional to the resistance, proportional, that is, to the extension or flexion of the elbow. This can be obtained by varying the length of the lever arms according to the position of the elbow, a process which is described below.

A pulley is situated at the level of the elbow which rotates by the flexion/extension movements of the forearm. At the level of the shoulder is a second pulley. These two pulleys are secured and linked together by a metal cable in such a way that the rotation of one leads to the rotation of the other. It is at the shoulder pulley that one finds the universal joint which transmits the pneumatic force. The joint is positioned in an offset fashion (like a cam) so that when the elbow is flexed the distance between the universal joint and the spherical support articulation is reduced. On the other hand, when the elbow is extended, the distance between the universal joint and the spherical support articulation is maximal, about twice as much as when the elbow is flexed. This arrangement ensures that the arm is in constant balance whether it is extended or flexed.

The system of connection by cable also has the advantage of harmonizing the movements of the shoulder and elbow. Thus abduction of the arm, alters the position of the universal joint and turns the shoulder-level pulley which leads to passive flexion of the elbow. Indeed, in everyday life abduction of the arm and flexion of the elbow are generally performed together.

Range of movement

Arm movements with the apparatus are made possible by the strength of the patient's muscles and the arrangement of the mechanical parts.

During numerous clinical tests, the passive ranges of movement permitted by the apparatus have been measured. They are as follows;

—shoulder abduction: 90°
—shoulder flexion: 135° (Fig. 3)
—shoulder adduction combined with flexion: 20°
—shoulder adduction combined with extension: 35°
—shoulder extension: 45°
—internal rotation of the arm: 90°
—external rotation of the arm: 80°
—flexion of the elbow: 120°
—extension of the elbow: 0° (complete)
—supination and pronation of the forearm: 90° (complete)

This great mobility on all levels is made possible by the use of the spherical support articulation, its location very near the centre of the scapulohumeral articulation, its connection with the universal joint and, finally, by the long movement of the cylinder piston.

Clinical tests

Clinical tests were carried out with 18 patients. Each patient had to;

—have a local deficiency of the arm, predominantly at the shoulder or throughout the arm, related to paralysis, muscular or rheumatic ailments, etc.
—have a muscular rating at the shoulder of around 2
—be alert and if possible co-operative.

The 18 patients suffered from various conditions;

—myopathy of the shoulder girdle
—paralysis of the brachial plexus with the major damage at C5 and C6
—hemiplegia
—tetraplegia
—reflex sympathetic dystrophy of the arm.

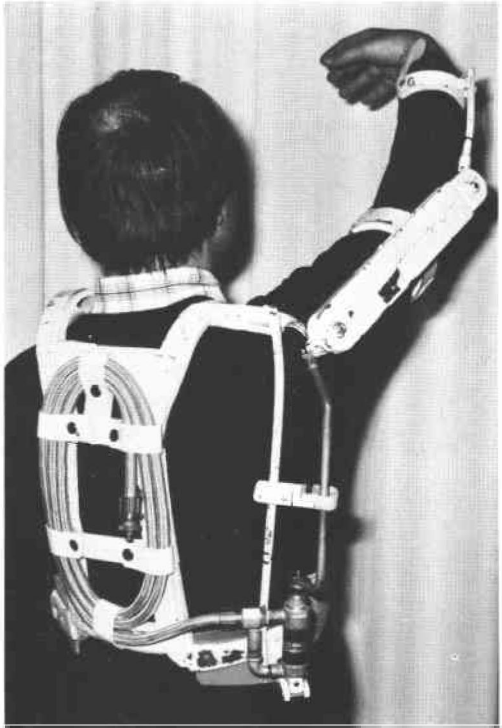

Fig. 3. During clinical tests shoulder flexion reached 135°.

The apparatus used for these tests was a prototype for the right side only and not perfectly adapted to each subject, a fact which led to some difficulties.

For each patient a dossier containing the following was compiled;

—evaluation of the handicapped patient
—evaluation of active mobility and the muscular force for all movements of the shoulder and elbow, first without and then with the Mobile Arm Support
—evaluation of usual movements, with and without the Mobile Arm Support.

Results

1 Tolerance

Tolerance to the support was excellent. Use of the apparatus caused no pain and did not aggravate the patient's condition.

The apparatus was well accepted; after fitting, the patient required no training in its use. The splint was immediately put into action by the force left in the arm and the subjects tested made use of it in the most natural way.

2 Gains in range of movements

a Shoulder movements.

Important gains were noted for nearly all movements of the arm, but especially for abduction and flexion (Fig. 4). Axial rotational movements were not affected by the apparatus which was not designed for this purpose.

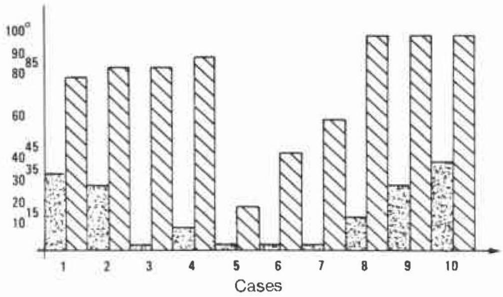

Fig. 4. Abduction of the shoulder in 10 cases of peripheral affliction. The grey area represents abduction without the support, the striped area shows the improvement produced by using the support.

b Flexion of the elbow.

Flexion of the elbow was improved in all cases except one (a hemiplegic) where no progress was made with or without the apparatus. The gain in elbow flexion is explained by two facts. Firstly, as the shoulder and elbow movements are linked by the apparatus, abduction of the arm favours flexion of the elbow. Secondly, when the arm is abducted and becomes horizontal, flexion of the elbow is accomplished more easily.

c Pronation-supination movements of the forearm.

They were not affected by use of the apparatus.

3 Gains in muscular strength

It was noted with some surprise that muscular strength was improved in one third of the cases, from about ½ to 1 point on the international rating scale. It is believed that the positioning of the arm and the effects of rest brought about by the supporting splint are responsible for this improvement; once the subject no longer has to fight the weight of his own arm, the arm muscles are more relaxed and can thus work better.

4 Lessening of pain

In cases of rheumatism of the shoulder in which functional inability is due largely to pain, the support provided by the splint permitted an immediate and painless resumption of movement. In these cases the Mobile Arm Support promises to be a useful instrument of rehabilitation.

5 Functional improvements

Improvement has been noted especially in cases of peripheral neurological conditions. These patients can write better, eat unaided, dress themselves, clean themselves and urinate normally.

The Mobile Arm Support improves functional movements in the greater part for all the patients fitted. In particular it permits patients to carry out activities more easily and with less fatigue (Fig. 5).

Fig. 5. Top, without the Mobile Arm Support a patient suffering from myopathy has to lean forward to don his spectacles. Bottom, normal action possible when using the support.

6 Negative effects

Negative effects have been very rare and are due largely to unsatisfactory adaptation of the prototype. The weight of the apparatus (4 kg) has been judged too high and must be reduced. Aesthetically the apparatus has been found acceptable.

The limitation of certain articular movements caused by the apparatus has not provided problems since the patients, due to their handicaps, were not able to reach the limits of the apparatus.

Application of the support

The type of apparatus and the results obtained offer hope for a large area of application. It is possible to use the support in a great number of illnesses and a variety of pathological states. It must be remembered, however, that the apparatus is only useful for weaknesses involving the shoulder joint.

Generally speaking, the apparatus can be used under two circumstances;

—temporarily; during the first stage of rehabilitation

—for prolonged and more definitive use during the last stage of rehabilitation.

As a result of experience with the apparatus it can be used temporarily in traumatic or painful rheumatic afflictions of the shoulder and in regressive neurological conditions, thereby allowing early movements and avoiding trophic problems.

The support is suitable for prolonged use in cases of marked brachial plexus, other myopathic scapulohumeral conditions, the aftermath of poliomyelitis, etc., especially if the other arm is also affected.

It can also be used in conjunction with another apparatus, for example, to cancel out the weight of a myo-electrical device or an apparatus needed to work the hand. The weight of a hand apparatus can be counterbalanced by the Mobile Arm Support.

Conclusions

1 The Mobile Arm Support is a simple, technically advanced apparatus which completely supports the arm thus allowing it to make use of its residual strength for functional activity. Its originality comes from the following;

—the splint is placed in contact with the arm

—it is supported by a harness and moves with the patient

—it functions on an elementary lever principle supported by a spherical articulation placed as close as possible to the scapulohumeral articulation

—it uses a pneumatic system that is both strong and supple

—the movements of the shoulder and elbow are linked.

2 The splint and handicapped arm form a hybrid system which functions as a single unit while using the patient's normal senses as well as his own strength. The apparatus is part and parcel of the handicapped patient, a point which favours its acceptance. Its utilization necessitates no long term learning.

3 Clinical tests have shown that the Mobile Arm Support has improved the active range in most shoulder and elbow movements as well as functional possibilities. Functional improvement was less marked than improvement in articular movements because most of the patients, although very handicapped, use, as best they can, the motor functions which are left to them.

4 The apparatus must be lightened, the harness must be individually fitted and its general aesthetics improved.

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