Patterns of Breathing of Patients Poliomyelitis and Respiratory Paralysis

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• Respiratory patterns of 67 patients with poliomyelitis were studied at the Respiratory and Rehabilitation Center, San Leandro, Calif. Electromyographic, pneumographic, fluoroscopic and clinical examinations were used to determine which muscles participated in ventilation. All the patients had diaphragmatic paralysis to a greater or lesser extent. Fourteen had complete paralysis of the diaphragm. With the exception of the 3 most severely involved patients, all used one or more groups of accessory muscles for quiet breathing. Details of the mechanism and effectiveness of breathing of these patients with abdomen, neck and chest muscles are discussed.

While the kinesiologic picture of normal respiration has been extensively studied,[1] little attention has been paid to the breathing patterns of patients with respiratory paralysis since the classical work of Duchenne[2] on patients with progressive muscular atrophy. Dail and Affeldt[3] mentioned four breathing patterns of patients with poliomyelitis and respiratory paralysis: breathing with the diaphragm, with accessory muscles of the neck, with the chest and with abdominal muscles. Glossopharyngeal breathing of patients with respiratory paralysis has been described by Dail.[4] Breathing by hyperextension of the trunk will be described in this paper.

This paper concerns the determination of the breathing pattern of patients with respiratory paralysis by correlating respiratory movements, muscular contractions and pulmonary ventilation.

Subjects

The subjects studied were 67 patients with respiratory paralysis resulting from poliomyelitis. Some were examined repeatedly at different stages of convalescence, but the majority were studied after maximum clinical recovery, i.e., from eighteen months to several years after the onset of paralysis. There were equal numbers of male and female subjects, ranging in age from 16 to 48 years. The vital capacity was below 25 per cent of the predicted normal value for 47 patients, between 25 and 50 per cent for 17 patients and between 50 and 75 per cent for 7 patients.

Methods

Respiratory movements were determined by clinical, fluoroscopic and pneumographic examination. Contraction of respiratory muscles was determined by electromyographic as well as clinical examination. Pulmonary ventilation was determined by pneumotachographic or spirometric study.

Respiratory Examination—Clinical examination was performed with the patient in the supine and sitting positions during quiet and deep breathing. It consisted of inspection and palpation of the thorax, abdomen and neck. The sternocleidomastoid, scalene, strip, platysma, pectoral (major and minor), intercostal and abdominal muscles were checked for contraction.

The following movements were recorded: cephalad displacement of the clavicle, sternum and ribs; epigastric, abdominal and lateral expansion of the chest and hyperextension of neck and back.

Fluoroscopic study was done with patients in both erect and recumbent positions whenever possible. Each hemidiaphragm was assessed separately by estimation of excursion of the dome in relation to the posterior part of the thoracic cage.

Pneumographic study was done during electromyographic recording. Simultaneous record-

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ing of expansion of chest and abdomen was possible with a Sanborn pneumograph connected to a strain gage and specially designed amplifier. Skin electrodes were applied at 16 sites on each side of the neck, chest and abdomen to determine the distribution of electrical activity in the sternocleidomastoid, anterior scalene, major and minor pectoral, intercostal, diaphragm, rectus abdominis and external oblique muscles. The recorder was an eight channel pen-writing oscillograph (Medcraft) modified for electromyographic studies. When interpretation of this recording was difficult additional studies of individual muscles were carried out with intramuscular wire electrodes and cathode ray oscilloscope.

Pneumotachographic and spirometric studies were done simultaneously with the electromyographic recording to relate the contraction of respiratory muscles to the respiratory phase.

Vital capacity was determined with a 13.5 liter Collins spirometer, and the predicted normal vital capacity was determined according to the nomogram of Collier, Ferris and Affeldt.[5] The percentage of the predicted normal vital capacity was used as a measure of the severity of respiratory paralysis.

Criteria for Determination of Breathing Patterns—Signs of diaphragmatic breathing were expansion of the epigastric region, abdomen and lateral lower part of the chest during inspiration; fluoroscopic observation of descent of the diaphragm on inspiration, and electromyographic observation of an interference pattern of action potentials during inspiration in the lower part of the chest, i.e., between the fifth and the ninth intercostal spaces.

Signs of neck breathing included upward movement of sternum and clavicle, visible and palpable contraction of muscles of the neck and electromyographic observation of an interference pattern of action potentials from the muscles of the neck during inspiration.

Clinical signs of abdominal breathing were abdominal retraction during expiration and tensing of the abdominal muscles during expiration. Fluoroscopic study showed elevation of the diaphragm on expiration, and the electromyograph recorded an interference pattern of action potentials from the abdominal muscles during expiration.

Clinical signs of chest breathing included expansion of the upper part of the chest and contraction of the pectoralis major and pectoralis minor, serratus anterior and intercostal muscles. The electromyograph recorded an interference pattern of action potentials from the same muscles.

Results and Comment

Diaphragmatic Breathers—Of the 67 patients examined, 14 had complete

Table 1: Quiet Breathing Entirely with the Diaphragm

Patient No.	Sex	Age	Vital Capacity	Percentage of Predicted Vital Capacity
39	F	36	775	26
41	F	33	810	26
43	M	32	1,080	27
45	F	30	880	29
46	M	28	1,180	29
47	M	16	1,140	32
48	F	47	925	34
49	F	24	1,100	34
50	M	37	1,540	35
51	F	32	1,150	36
52	F	38	1,090	37
53	F	23	1,250	38
54	M	45	1,700	40
55	M	28	1,860	43
56	M	53	1,750	43
57	M	35	1,775	44
58	F	42	1,350	45
59	M	33	1,775	45
60	M	37	1,900	46
61	M	50	1,825	46
62	M	38	2,100	50
63	M	48	2,175	54
64	M	25	2,600	57
65	M	36	2,400	60
66	M	33	2,700	65
67	F	29	2,300	66

Table 2: Quiet Breathing Entirely with Accessory Muscles

Patient No.	Sex	Age	Vital Capacity	Percentage of Predicted Vital Capacity	Hyper-extension of Trunk	Activity of Respiratory Muscles: Neck	Chest	Abdomen
1	F	34	0	0	0	0	0	0
2	F	35	35	1	0	0	0	0
3	M	22	50	1	0	0	0	0
4	F	43	50	2	0	+	0	0
5	F	35	110	3	+	+	0	0
7	M	22	390	8	0	+	0	+
16	M	26	500	12	*	+	0	0
17	F	33	420	14	+	+	+	0
21	F	28	460	15	+	+	0	+
22	M	40	600	15	0	+	0	0
23	M	48	615	15	*	+	+	0
26	M	34	800	19	+	0	0	+
35	F	28	725	23	*	+	+	+
37	F	54	675	25	0	+	0	+

0 Inactive
+ Active
**Not Recorded

Table 3: Abdominal Breathers

Patient No.	Sex	Age	Vital Capacity (supine)	Percentage of Predicted Vital Capacity	Vital Capacity (sitting)	Percentage of Predicted Vital Capacity	Activity of Respiratory Muscles Diaphragm	Neck	Chest	Abdomen
7	M	22	390	8	550	11	0	+	0	+
9	M	48	350	9	210	5	+	+	+	+
10	M	18	425	9	1,175	26	0	0	+	+
19	F	23	450	14	500	15	+	+	0	+
20	F	46	400	14	400	14	+	0	0	+
21	F	28	460	14	455	14	0	+	0	+
24	F	20	510	16	550	18	+	+	0	+
26	M	34	800	19	1,325	31	0	0	0	+
32	F	31	725	22	600	18	+	0	0	+
35	F	28	725	23	1,025	32	0	+	+	+
37	F	54	625	25	1,200	46	0	+	0	+
42	F	36	750	25	1,020	34	+	+	0	+

paralysis of the diaphragm and breathed with accessory muscles only, and 53 were diaphragmatic breathers. Of the 53 diaphragmatic breathers, 26 breathed entirely with the diaphragm, and 27 breathed with the diaphragm and accessory muscles.

All who breathed entirely with the diaphragm (table 1) had a vital capacity above 25 per cent of the predicted normal value, and all the patients with complete paralysis of the diaphragm (table 2) had a vital capacity below 25 per cent of the predicted normal value. This would tend to support Wade's[1a] estimate that normally about one fourth of the ventilation in vital capacity is due to chest expansion and three fourths to movement of the diaphragm.

Abdominal Breathers — Twelve patients had expiratory abdominal contraction (table 3). According to vital capacity, they could be divided into two groups: (1) 7 patients whose vital capacity when they were both supine and sitting was less than 25 per cent of their predicted vital capacity, and (2) 5 patients whose vital capacity was less than 25 per cent of their predicted value when they were supine but more than 25 per cent of the predicted value when they were sitting.

The patients in group 1 breathed with a combination of muscles and had no characteristic pattern (table 4). They required respiratory aid most of the time.

Patients in group 2 were able to walk and sit without respiratory aid but needed respiratory aid when supine. Four of them had severe paralysis of the neck and upper extremities, but the muscles of trunk and lower extremities were preserved. All had marked paralysis of the diaphragm, 3 of them complete paralysis. Their ventilation was effected by abdominal contraction, which produced active expiration. This was followed by passive inspiration. They were essentially expiratory breathers, with low inspiratory capacity. In the upright position they benefited from the normal increase in expiratory reserve volume due to the downward shift of the diaphragm. This increased

Table 4: Quiet Breathing with Diaphragm and Accessory Muscles

Patient No.	Sex	Age	Vital Capacity	Percentage of Predicted Vital Capacity	Activity of Respiratory Muscles Diaphragm	Neck	Chest	Abdomen
6	F	45	100	3	+	+	0	0
8	M	30	400	9	+	+	0	0
9	M	48	350	9	+	+	+	+
10	M	18	425	9	+	0	+	+
11	M	42	400	9	+	+	+	0
12	M	26	440	10	+	+	0	0
13	M	15	350	10	+	+	+	0
14	M	20	400	10	+	+	+	0
15	F	30	355	11	+	+	0	0
18	F	30	425	14	+	+	0	0
19	F	23	450	14	+	+	0	+
20	F	46	400	14	+	0	0	+
24	F	20	510	16	+	+	0	+
25	F	27	560	16	+	+	0	0
27	F	32	600	20	+	+	0	0
28	F	33	590	20	+	+	+	0
29	M	18	875	21	+	+	0	0
30	F	39	700	21	+	+	0	0
31	M	23	1,000	22	+	+	0	0
32	F	31	725	22	+	0	0	+
33	M	29	1,000	22	+	+	+	0
34	M	29	1,050	22	+	+	0	0
36	M	31	1,025	24	+	+	0	0
38	F	18	825	25	+	+	0	0
40	F	36	750	25	+	0	0	0
42	M	41	1,120	26	+	+	0	+
44	M	38	1,175	27	+	+	0	0

their vital capacity between 300 and 500 cc.

Neck Breathers—There were 33 neck breathers, all with vital capacity below 30 per cent of the predicted normal value. Most of these patients had neck muscles rated less than fair. Nevertheless, there was ample evidence that the neck muscles played an important part in breathing, since in some patients breathing was embarrassed when the neck was flexed. In addition, there were 4 patients who breathed entirely with the neck (table 2). Ten of the neck breathers had associated hyperextension of the trunk.

Trunk Breathers—A number of patients using accessory muscles for quiet breathing had rhythmic hyperextension of the trunk on inspiration and flexion on expiration. This was present when they were in both supine and sitting positions. The activating muscles seemed to vary with the patient and the position. They have not been studied in detail.

At the end of a deep inspiration, normal subjects contract paravertebral muscles[1c] and hyperextend the trunk, but it has been reported[1a] that this motion does not increase the vital capacity. It may facilitate the inspiratory action of muscles of neck and chest.

The importance of recognizing this accessory mechanism is illustrated by the effect of total spinal fusion on a patient who had used hyperextension of the trunk as an accessory method of breathing. Spinal fusion led to considerable reduction in vital capacity and increased the requirement of respiratory aid.

Respirometric study of a fresh cadaver with an endotracheal tube indicated that passive hyperextension and flexion of the trunk can produce a flow of 200 cc. of air.

Chest Breathers — Only 10 patients showed inspiratory contractions of the pectoralis major and pectoralis minor during quiet breathing. In no instance could significant inspiratory or expiratory contractions of intercostal muscles, at least anteriorly, be demonstrated clinically or electromyographically. Not only was their no patient in our series who breathed entirely with the chest, but the activity of the chest muscles observed during quiet breathing usually was limited to one or two muscles.

Conclusion

In the group of patients studied, complete paralysis of the diaphragm always led to severe respiratory impairment despite the activity of accessory muscles. Most effective as accessory muscles when the patient was upright were the abdominal muscles. Next in effectiveness were the accessory muscles of the neck, with or without associated hyperextension of the trunk. The considerably lower value of the neck muscles as accessories is explained by the fact that they were always considerably involved in patients with paralysis of the diaphragm.

Least effective as accessory muscles were those of the chest. Little activity of those muscles was observed during quiet breathing, even in patients in whom their activity during deep breathing and flexion of the trunk was demonstrated electromyographically.

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