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The Mid-Term Changes of Pulmonary Function Tests After Phrenic Nerve Transfer

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Abstract

Background: In the restoration of elbow flexion, the phrenic nerve has proven to be a good donor, but considering the role of the phrenic nerve in respiratory function, we cannot disregard the potential dangers of this method.
Objectives: In the current study, we reviewed the results of pulmonary function tests (PFT) in four patients who underwent phrenic nerve transfer.
Patients and Methods: We reviewed the results of serial spirometry tests, which were performed before and after phrenic nerve transfer surgery.
Results: All patients regained Biceps power to M3 strength or above. None of our patients experienced pulmonary problems or respiratory complaints, but a significant reduction of spirometric parameters occurred after surgery.
Conclusions: This study highlights the close link between the role of the phrenic nerve and pulmonary function, such that the use of this nerve as a transfer donor leads to spirometric impairments.

Keywords: Phrenic Nerve Transfer, Pulmonary Function Tests, Elbow

1. Background

A traumatic injury of the brachial plexus, the web of large nerves that conduct signals to the shoulder, arm and hand, can lead to partial or total denervation of the muscles of the upper extremities. Without proper and timely diagnosis and treatment, these are devastating injuries causing lifelong immobility (1). Although recovery takes place spontaneously in most patients, surgical intervention is required when clinical or electrical reserve does not start within the three to six months after the injury (2).

Developments in microsurgery now have good success in brachial plexus restoration, and through treatments, such as neurolysis, nerve grafting, or nerve transfer (neurotization), patients can achieve rational mobility. Nerve transfer is a treatment option when root injuries involve the avulsion of the spinal nerve and proximal stumps are not accessible. During this procedure, a functional but less important nerve is transferred to the denervated nerve, which is functionally more important. Various nerves, such as the phrenic nerve (3), intercostal nerves (4), the medial pectoral nerve, (5) and the spinal accessory nerve (6) can be used as the source of transfer. The restoration of elbow flexion is the most important aim of any surgical treatment for severe brachial plexus injury, and the phrenic nerve alone or in combination with multiple intercostal nerves has proved to be a good donor. However, considering the role of the phrenic nerve in respiratory function, we cannot disregard the potential dangers. Some studies have revealed no significant reduction in pulmonary function subsequent to phrenic nerve transfer, but there are some reports of an effect on respiratory function in the long term.

2. Objectives

In the current study, we reviewed the results of pulmonary function tests (PFT) in four patients who underwent phrenic nerve transfer.

3. Patients and Methods

Our study included patients with total or partial lesions of the brachial plexus that did not recover spontaneously after 3 - 6 months and who underwent unilateral phrenic nerve transfer to treat post-traumatic global root avulsion from August 2012 to August 2013. The exclusion criteria were: age > 60 years and presence of pulmonary disease such as COPD, asthma, and atelectasis. This study was approved by the ethical board of Iran University of Medical Sciences (IUMS), and informed consent was obtained from all patients.

The injury was detected by physical examination and confirmed by preoperative and intraoperative electromyography (EMG) and intraoperative exploration. We reviewed the results of serial spirometries, which were performed before and after phrenic nerve transfer surgery.

The spirometry was performed with a computer-assisted spirometer (Pulmolab 435-spiro 235, Morgan, England) and according to international guidelines (7). The spirometric measurements were related to the predicted values for each patient.

3.1. Statistical Analysis

Descriptive statistical analyses were performed and quantitative spirometric parameters were reported as the best measure for each value.

4. Results

There were five patients who underwent phrenic nerve transfer for brachial plexus injury. All patients were male. The time interval between the injury and the nerve transfer was 3 - 6 months. All patients regained Biceps power to M3 strength or above. The lung function measurements are shown in detail in Tables 1 - 4. One patient did not return for pulmonary function tests after surgery. None of our patients experienced pulmonary problems or respiratory complaints, but a significant reduction of spirometric parameters occurred after surgery.

Table 1. Patient 1, Date of Trauma :2013.05.18 , Date of Surgery :2013.08.17

Spirometry	Predicted Value	Date			
		2013.05.16	2013.10.15	2013.11.12	2014.04.06
VC EX, L	5.08	4.89	3.76	3.62	3.65
VC In, L	5.08	4.63	3.71	3.47	3.42
MV, L/min	11.00	35.01	30.23	28.94	30.87
ERV, L	1.64	1.53	0.68	0.75	0.79
IRV, L	NA	NA	NA	0.69	NA
FEV 0.5, L	NA	3.62	2.6	2.35	2.67
FEV 1, L	4.14	4.46	3.19	2.99	3.18
FEV 2, L	NA	4.89	3.56	3.37	3.52
FEV 3, L	NA	4.89	3.63	3.55	3.58
FEV 1% FVC, %	NA	91.26	89.02	82.61	87.08
FEV 1% VC MAX, %	82.71	91.26	89.02	82.61	87.08
MVV, L/min	149.78	NA	NA	NA	NA
T EX, s	NA	1.86	2.44	NA	2.1
TEX/TTOT	NA	0.53	0.56	0.59	0.58
MIF, L/s	NA	1.24	1.15	1.17	1.22
MEF, L/s	NA	NA	NA	0.82	NA
FVC, L	4.86	4.89	3.63	3.62	3.65
FET, s	NA	NA	NA	4.62	NA
FEF 25, L/s	8.14	9.94	7.78	6.11	7.06
FEF 50, L/s	5.36	6.8	4.53	3.12	4.94
FEF 75, L/s	2.47	2.6	1.65	1.11	1.6
PEF, L/s	9.57	9.94	9.91	8.11	7.65
PIF, L/s	NA	NA	NA	4.5	NA
FEF 50% FVC, %	110.45	139.04	132.62	86.26	135.24
MMEF 75/25, L/s	4.94	5.9	3.74	2.74	4.0
FEF 75/85, L/s	1.63	2.07	1.21	0.79	0.95
FEF 50 FIF 50, %	NA	109.63	104.89	72.68	103.5
ATS-accepted (1 = yes)	NA	NA	NA	0.00	NA

Abbreviation: NA, not available.

Table 2. Patient 2, Date of Trauma :2013.03.24 , Date of Surgery: 2013.05.29

Spirometry	Predicted Value	Date	
		2013.05.26	2013.08.03
VC EX, L	4.81	3.05	NA
VC In, L	4.81	3.23	NA
MV, L/min	8.43	23.66	NA
ERV, L	1.43	1.27	NA
IRV, L	NA	0.81	NA
FEV 0.5, L	NA	2.13	NA
FEV 1, L	3.83	2.82	2.27
FEV 2, L	NA	3.01	NA
FEV 3, L	NA	3.05	NA
FEV 1% FVC, %	NA	92.42	97
FEV 1% VC MAX, %	80.55	87.35	NA
MVV, L/min	137.10	NA	NA
T EX, s	NA	NA	NA
TEX/TTOT	NA	0.53	NA
MIF, L/s	NA	0.85	NA
MEF, L/s	NA	0.74	NA
FVC, L	4.61	3.05	2.34
FET, s	NA	2.54	NA
FEF 25, L/s	7.85	5.92	5.08
FEF 50, L/s	5.02	3.24	3.48
FEF 75, L/s	2.19	1.64	1.89
PEF, L/s	9.12	6.74	5.32
PIF, L/s	NA	5.64	4.73
FEF 50% FVC, %	109.05	106.43	NA
MMEF 75/25, L/s	4.45	3.09	3.45
FEF 75/85, L/s	1.24	1.50	NA
FEF 50% FIF 50, %	NA	63.72	NA
ATS-accepted (1 = yes)	NA	0.00	NA

Abbreviation: NA, not available.

Table 3. Patient 3, Date of Trauma :2013.09.16, Date of Sutgery :2014.02.01

Spirometry	Predicted Value	Date	
		2013.12.26	2014.06.17
VC EX, L	5.51	4.16	3.8
VC In, L	5.51	4.04	3.94
MV, L/min	11.71	35.38	34.95
ERV, L	1.69	1.43	1.14
IRV, L	NA	1.07	1.02
FEV 0.5, L	NA	3.24	2.8
FEV 1, L	4.44	3.9	3.47
FEV 2 L	NA	4.12	3.74
FEV 3, L	NA	4.16	3.77
FEV 1% FVC, %	NA	93.77	91.49
FEV 1 % VC MAX, %	82.71	93.77	88.06
MVV, L/min	156.50	NA	NA
T EX, s	NA	NA	NA
TEX/TTOT	NA	0.56	0.56
MIF, L/s	NA	1.33	1.33
MEF, L/s	NA	1.06	1.03
FVC, L	5.26	4.16	3.8
FET, s	NA	2.01	3.15
FEF 25, L/s	8.52	8.91	7.49
FEF 50, L/s	5.62	6.31	4.95
FEF 75, L/s	2.66	2.72	1.89
PEF, L/s	10.00	9.06	7.56
PIF, L/s	NA	5.12	5.4
FEF 50 % FVC, %	106.99	151.73	130.43
MMEF 75/25, L/s	5.08	5.92	4.39
FEF 75/85, L/s	1.62	2.04	1.12
FEF 50 % FIF 50, %	NA	137.12	104.25
ATS-accepted (1=yes)	NA	0.00	0.00

Abbreviation: NA, not available.

Table 4. Patient 4, Date of Trauma : 2013.08.16 , Date of Surgery :2014.01.03

Spirometry	Predicted Value	Date		
		2014.01.01	2014.02.06	2014.04.08
VC EX, L	5.05	4.64	4.52	4.73
VC In, L	5.05	4.39	4.37	4.48
MV, L/min	10.86	26.71	24.01	21.35
ERV, L	1.47	1.58	1.31	0.82
IRV, L	NA	0.99	1.51	1.83
FEV 0.5, L	NA	2.97	2.9	3.16
FEV 1, L	4.01	3.72	3.62	3.92
FEV 2, L	NA	4.22	4.09	4.34
FEV 3, L	NA	4.44	4.3	4.56
FEV 1% FVC, %	NA	80.18	79.96	82.82
FEV 1 % VC MAX, %	80.55	80.18	79.96	82.82
MVV, L/min	141.88	NA	NA	NA
T EX, s	NA	NA	NA	NA
TEX/TTOT	NA	0.49	0.54	0.54
MIF, L/s	NA	0.87	0.87	0.78
MEF, L/s	NA	0.91	0.74	0.66
FVC, L	4.84	4.64	4.52	4.73
FET, s	NA	6.61	6.06	5.76
FEF 25, L/s	8.07	7.12	7.6	7.87
FEF 50, L/s	5.17	4.76	3.74	4.55
FEF 75, L/s	2.29	1.35	1.18	1.44
PEF, L/s	9.37	7.68	9.82	9.08
PIF, L/s	NA	3.83	4.62	5.13
FEF 50 % FVC, %	106.99	102.54	82.73	96.13
MMEF 75/25, L/s	4.52	3.69	3.22	3.82
FEF 75/85, L/s	1.26	0.82	0.7	0.88
FEF 50% FIF 50, %	NA	173.05	84.23	115.78
ATS-accepted (1=yes)	NA	0.00	0.00	0.00

Abbreviation: NA, not available.

5. Discussion

Reviewing our experience with patients who underwent phrenic nerve transfer, we confirmed previous reports of spirometric impairments. The most common parameters used to interpret lung function in spirometry are VC, FEV1, FEV1/VC ratio and TLC. Although FVC is frequently used instead of VC, the measured value of VC on inspiration (IVC), slow expiration (SVC) or forced expiration are more exact. The first finding of our study was the reduction of VC on both inspiration and expiration.

Secondly, the values of FEV1 and FVC were impaired.

FEV1 decreased to < 80% of predicted values, and concomitantly, a decrease occurred in FVC, while the FEV1/FVC ratio was normal or even increased. This pattern most often happens when the patient cannot inhale or exhale successfully. A study by Chaliadapong et al. also showed a significant reduction of pulmonary function one year after phrenic nerve transfer surgery (8). Similar to our findings, Beraldo et al. reported a significant reduction of FVC and FEV1 to 69% and 68% of predicted values, respectively. But in contrast, they also found a reduction of the FEV1/FVC ratio to 81% of predicted value, which was increased in our patients (9). The reduced VC in combination with the increased FEV1/VC (> 85 - 90%) and the convex pattern of the flow-volume curve proposes a submaximal inspiratory or expiratory effort (7). It also results in an increase in the RV, because the patients could not exhale long enough to empty the lungs from RV. These changes look to be the result of the inability of weakened muscles to force thoracic volume. Peak expiratory flow (PEF) was the other parameter that decreased after the surgery. It can be affected prior to FEV1 and FVC and represent the poor initial effort. Since MVV (maximal voluntary ventilation) correlates well with FEV1, it is not usually reported in PFT results. However, a disproportionate decline relative to FEV1 can indicate neuromuscular disorders (10).

The results show that our patients did not improve with time after surgery. In contrast to our study, Beraldo et al. found an improvement of spirometric parameters with time after surgery (9).

5.1. Conclusions

This study highlights the close link between the role of the phrenic nerve and pulmonary function, such that the use of this nerve as a transfer donor leads to spirometric impairments.

Footnote

Authors' Contribution: Masoud Yavari (study concept, design and supervision), Seyed Esmail Hassanpour (study concept and design), Mohammad Khodayari (Data collection and analysis and manuscript writing).

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