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Impact of burn contractures of chest wall and their surgical release on pulmonary function

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ABSTRACT

Background: Extensive burn scars and contractures are likely to restrict the movements of the chest wall which may affect the pulmonary ventilation by restricting its expansion during inspiration. We designed this study to evaluate the effect of burn contractures of chest wall on pulmonary function and to estimate the effect of contracture release on pulmonary functions in patients with compromised PFT.

Methods: Pulmonary function tests (PFT) of 20 patients having chest wall contractures involving more than 50% of the chest circumference were studied. Restrictive lung disease was defined as forced vital capacity (FVC) value less than 80% of predicted normal for the age, weight, and height of that patient. Patients with a restrictive pattern on PFT were subjected to the surgical release of the contracture. PFT was repeated one month after the surgery which was compared with the initial report.

Results: Of the 20 patients included in the study, 5 (25%) patients had a restriction pattern on PFT. 1 patient had a mild restriction, 2 patients had moderate restriction and 2 patients had a severe restriction of pulmonary function. The mean duration of contracture was 58.2 ±15.75 months in patients with a pulmonary restriction as compared to 29.87 ±6.21 months in patients with a normal PFT ($p=0.001$). All patients having a restrictive pattern on PFT had contracture involvement of >75% of the chest wall circumference ($p=0.0036$). The mean forced vital capacity (FVC) increased from 1.94 L preoperatively to 2.11 L after surgical release of the contracture ($p=0.047$). However, the restriction pattern in PFT did remain.

Conclusion: Long standing chest wall contractures and contractures involving >75% of the chest circumference are likely to cause a restrictive pattern on PFT. Any significant improvement of pulmonary function after surgical release of the contracture is unlikely.

Abbreviations: PFT, pulmonary function test; FVC, forced vital capacity; FEV1, forced expiratory volume at 1s; MVV, maximal voluntary ventilation; TLC, total lung capacity; VC, vital capacity; MEF, maximal expiratory flow; SD, standard deviation; SPSS, statistical package for social sciences.

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1. Introduction

Contracture formation is among the commonly observed sequelae after burn injuries. Deep dermal and full thickness burns heal by secondary intention leading to extensive scarring and wound contraction [1,2]. Clinically, contracture is defined as tissue shortening or distortion that causes decreased joint mobility and function [3].

Involvement of the limb leads to deformities like flexion or extension contractures of the fingers, adduction deformity of the thumb due to contracture of the first webspace, flexion contracture of the elbow, restriction of shoulder abduction, etc. When scars of the neck contract, they produce unsightly deformities like the restriction of neck extension, webbing in the neck skin and in severe cases, mento-sternal adhesion [4]. On the same principle, when the extensive burn scars of the chest wall contract, they are likely to restrict the movement of the ribcage. This may have a negative impact on the ventilation of the lungs by restricting its expansion during inspiration.

Gonzalez et al. [5] studied the effect of chest wall restriction on pulmonary function test (PFT). They used a restrictive device, which consisted of two inflatable pads inside a two-piece fiberglass shell that encompassed the thorax of the subject. The device hindered inspiration only when the pads were inflated with air. They found that chest wall restriction decreases forced vital capacity (FVC), forced expiratory volume at 1 s (FEV1), and maximum voluntary ventilation (MVV) by 8%, 11%, and 10%, respectively. Experimental study by Cline et al. [6,7] also studied the effect of chest wall restriction on PFT in healthy volunteers. They reported a 12% decrease in FVC. Neil and Dissanaike [8] reported a case of a patient with chest wall scaring presenting with exertional dyspnea, which improved after contracture release surgery.

Based on these experimental studies, we hypothesized that chest wall contractures lead to a restrictive pattern in PFT and that the pulmonary function can be improved after surgical release of these contractures. This study aimed to evaluate the effect of burn contractures of the chest wall on pulmonary function and to estimate the effect of contracture release on pulmonary functions in patients with a compromised PFT.

2. Methods

This study was conducted at the department of burns, plastic and maxillofacial surgery of a tertiary care hospital over a period of 18 months. A total of 20 patients between the age of 18–60 years with burn scars/contractures involving at least half the chest circumference were studied. Patients with pre-existing chest wall deformities, chronic obstructive pulmonary disease, and interstitial lung disease were excluded from the study.

Clearance for the study was obtained from the institutional ethical committee. Patients enrolled for this study were explained about the pulmonary function testing and the contracture release surgery. A written consent was obtained from the patients. Patients were then evaluated by pulmonary function tests using Medisoft Spiro Air machine by the pulmonologist. Various lung volumes and capacities were measured and recorded.

In patients with obstructive lung disease, there is a decrease in expiratory flow rate. With fully established obstructive lung disease, the FEV1/FVC ratio is decreased and the total lung capacity is either normal or increased. FEV1/FVC ratio of <80% is considered as diagnostic for obstructive lung disease [9]. Restrictive pattern on PFT is characterized by the decrease in lung volumes, primarily, total lung capacity (TLC), vital capacity (VC), forced expiratory volume at 1 s (FEV1), and forced vital capacity (FVC). Although above mentioned volumes and capacities are reduced in restrictive diseases of the lung, reduced FVC is the hallmark of the restrictive lung disease. Therefore, we defined restrictive lung disease as FVC value less than 80% of the predicted normal for the age, weight, and height of the patient [9–11]. Restrictive disease was further classified as mild (70–79%), moderate (50–69%) and severe (<50%) depending on the percentage of the predicted FVC observed [12,13].

Patients with a restrictive pattern on PFT underwent surgery to release their chest wall contractures. Midline release of the anterior chest wall was performed in all patients along with the release of the associated neck or axillae contractures. The defect created was resurfaced with intermediate thickness split skin graft harvested from the thigh. This was performed as a routine practice in the Institute.

PFT was repeated one month after the surgery which was compared with the initial report. Results were compared to assess whether there is any improvement in the pulmonary functions.

2.1. *Statistical analysis*

Categorical variables were presented in number and percentage (%) and continuous variables were presented as mean ±standard deviation (SD). Normality of the data was tested by Kolmogorov–Smirnov test. If the normality was rejected then non-parametric test was used. Age was compared using Unpaired t-test and duration of contracture was compared using Mann–Whitney Test between the two groups. Paired T test was used for comparison between preoperative, predicted and postoperative values of PFT. Qualitative variables were correlated using Fisher's exact test/Chi square test. A p value of <0.05 was considered statistically significant. The data was entered in Microsoft excel spreadsheet and analysis was done using Statistical Package for Social Sciences (SPSS) version 21.0.

3. Results

Of the 20 patients included in the study, 10 patients (50%) were in the age group of 18–25 years, 6 (30%) were in the age group of 26–30 years and 4 patients (20%) belonged to the age group of 36–40 years (Fig. 1). 7 patients (35%) were males and 13 patients (65%) were females. 4 patients had history of smoking.

Different PFT parameters like FVC, FEV1, FEV1/FVC ratio and MEF (maximal expiratory flow) were assessed individually, with respect to their predicted value and their relationship to each other to categorize the patients into normal PFT group

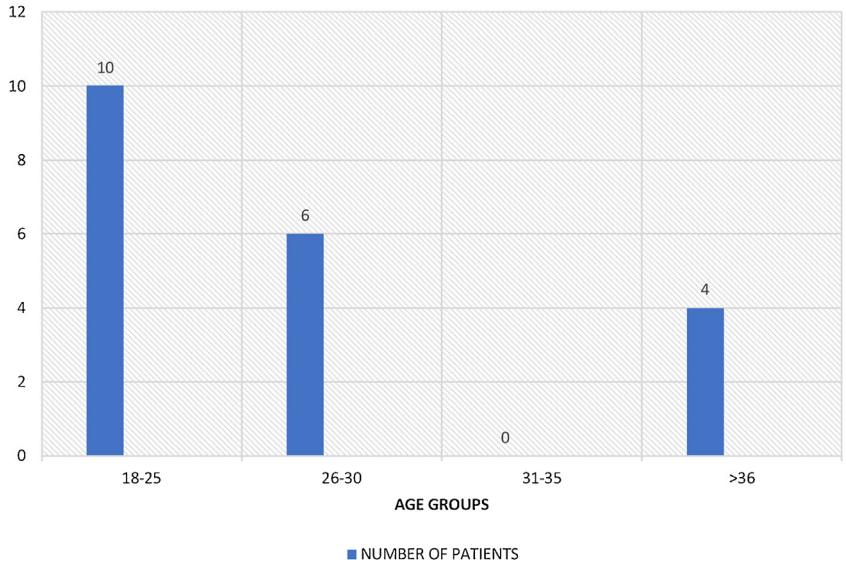

Fig. 1 – Age distribution of the patients with chest wall contracture.

and restrictive pattern group. Normal PFT values were observed in 15 (75%) patients. Whereas, 5 patients (25%) had evidence of a restrictive pattern in their PFT. None of the patients had obstructive pattern on PFT.

A statistically significant difference was found in the mean duration of presentation in restrictive pattern group and normal pattern group. The mean duration from the date of burn to the date of presentation of the patient was 58.2 ±15.75 months in restrictive pattern group and 29.87 ±6.21 months in patients with normal pattern group (p=0.001) (Table 1).

The 5 patients diagnosed with a restrictive disorder on PFT were further categorized as having mild, moderate and severe restriction depending on the percentage of the predicted FVC (70–79% — mild restriction; 50–69% — moderate restriction; <50% — severe restriction). It was observed that 1(20%) patient had a mild restriction, 2(40%) had moderate restriction and 2 patients (40%) had a severe restriction on PFT.

Twelve patients had involvement of 50–75% of chest circumference while 8 patients had involvement of >75% of chest circumference. None of the patients in the 50–75% group had a restrictive pattern in PFT, while 5 out of 8(62.5%) patients in the >75% group had a restrictive pattern in PFT (p=0.0036) (Table 1).

Five patients with the restrictive pattern were operated to release the chest wall contractures. All the operated patients had an improvement in their pulmonary functions after the surgical release (Table 2).

A statistically significant increase in the mean FVC from 1.94L to 2.11L was observed after surgical release of the chest wall contracture (p=0.047) (Fig. 2). The mean FEV1 increased from 1.74L to 1.91L after the contracture release. (p=0.056). The mean FEV1/FVC ratio increased from 88.89% to 89.25% postoperatively (p=0.842). An insignificant increase of the mean MEF was observed from a preoperative value of 2.23L/S to 2.68L/S (p=0.125).

4. Discussion

Although the age limit of patients was 18–60 years in this study, all our patients were below 40 years of age. This is because burn injuries are more common in young and active age group. Also, the prognosis of acute burns is relatively better in a younger

Table 1 – Distribution of the various parameters between normal and restrictive pattern on pulmonary function test (PFT).

		Normal PFT	Restrictive pattern	p Value
Number of patients (n)		15 (75%)	5 (25%)	0.044
Mean age (years)		25.27±6.52	27.8±9.58	0.511
Sex	Male	5 (71.42%)	2 (28.57%)	1.000
	Female	10 (76.92%)	3 (23.07%)	
Smoking	No	12 (75%)	4 (25%)	1.000
	Yes	3 (75%)	1 (25%)	
Mean duration of contracture (months)		29.87±6.21	58.2±15.75	0.001
Extent of contracture (% of chest circumference)				
50%–75%		12 (100%)	0 (0%)	0.0036
>75%		3(37.5%)	5 (62.5%)	

Table 2 – Comparison of FVC, FEV1, FEV1/FVC and MEF before and after the contracture release in patients with restrictive pattern on PFT. (FVC- Forced vital capacity; FEV1- Forced expiratory volume in 1s; FEV1/FVC- ratio showing the percentage of the forced expiratory volume expired in one second; MEF- maximal expiratory flow).

		Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Mean	p Value
FVC (liters)	Predicted	3.53	4.82	2.77	3.66	3.22	3.60	0.007
	Preoperative	2.27	2.25	2.12	1.63	1.43	1.94	0.047
	Postoperative	2.44	2.64	2.20	1.66	1.64	2.11	
	Improvement	0.17	0.39	0.08	0.03	0.21	0.17	
FEV1 (liters)	Predicted	3.07	4.15	2.38	3.14	2.82	3.11	0.006
	Preoperative	2.00	2.25	1.88	1.48	1.12	1.74	0.056
	Postoperative	2.12	2.28	1.96	1.86	1.33	1.91	
	Improvement	0.12	0.03	0.08	0.38	0.21	0.16	
FEV1/FVC (%)	Predicted	83.72	83.61	81.43	80.80	85.41	82.99	0.218
	Preoperative	88.21	92.94	86.29	98.67	78.36	88.89	0.842
	Postoperative	88.08	98.06	81.48	97.43	81.24	89.25	
MEF (liters/second)	Predicted	4.00	5.10	3.47	4.17	4.15	4.17	0.003
	Preoperative	2.03	3.60	2.30	2.10	1.13	2.23	0.125
	Postoperative	1.98	4.80	2.28	2.83	1.55	2.68	

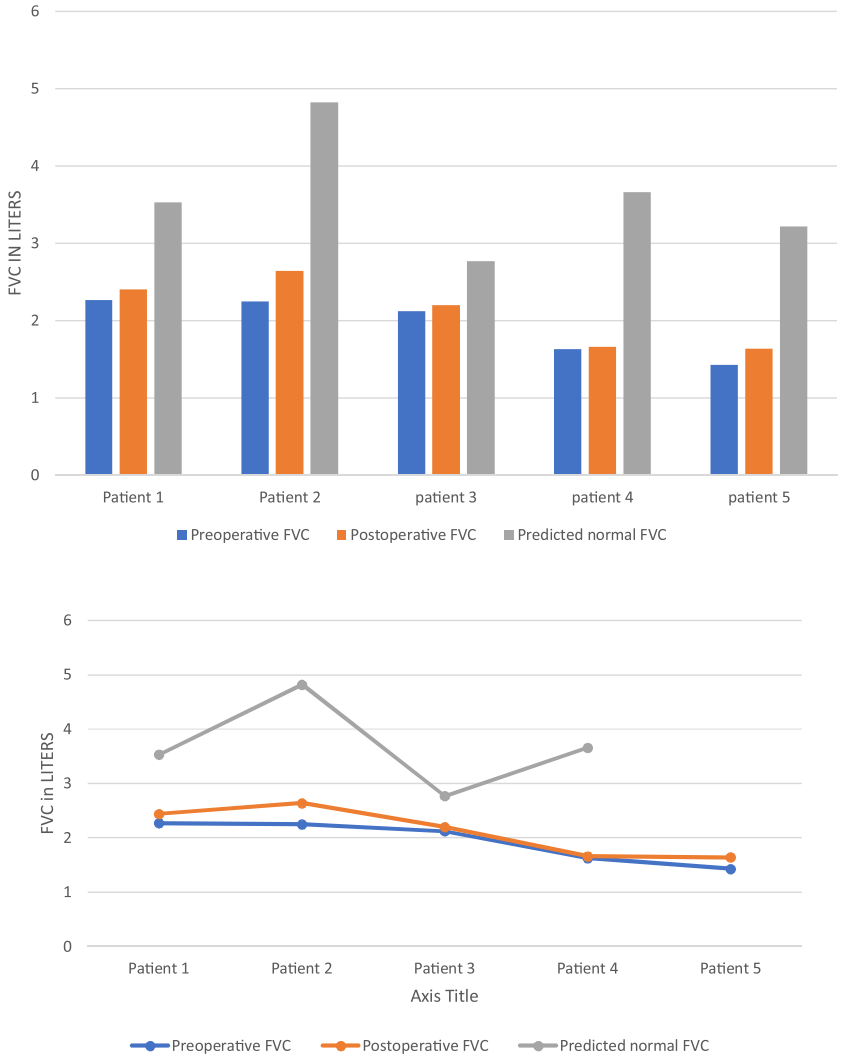

Fig. 2 – Comparison of FVC before and after the contracture release in patients showing restrictive pattern on PFT. (FVC- forced vital capacity; PFT- pulmonary function test).

age group, who subsequently survive to develop contractures. As burn contracture is a functionally disabling condition, patients seek early medical attention for correction of the contractures and improving function.

This study shows that a significant number of patients (75%) did not have a restrictive pattern even when they had chest wall contractures involving more than 50 percent of the circumference. It may be that the scar contracture of the chest wall causes gradually increasing constriction of the chest wall giving the body an ample time to adapt, in contrast to the above mentioned experimental studies, where the constriction was sudden onset with the application of the chest wall constrictor device [5–7]. The body may adapt to the gradual chest constriction by increasing the mobility of the diaphragm as a compensatory mechanism.

We correlated the severity of restriction with the extent of chest wall contracture. In this study, all patients with a restrictive pattern on PFT had chest wall involvement of >75% of the circumference, indicating that only extensive chest wall contractures lead to restrictive lung disease. In the experimental study by Gonzalez et al., they used chest restrictor device encircling whole of the thorax (i.e. 100% of the circumference) and created a restrictive pattern in PFT. In contrast, we included patients with chest wall contractures of >50% of the chest circumference.

The patients with restrictive pattern also had a longer duration of the disease as compared to the patients without a restrictive pattern. The mean duration of contracture in patients with the restrictive disease was 58.2 months. Whereas it was 29.87 months in patients with normal PFT indicating that the longer duration of scar contracture increases the possibility of pulmonary restrictive disease. In this study, we found that the restriction was mild in 1 patient, moderate in 2 patients and severe in 2 patients. The preoperative and postoperative photographs of representative patients are shown in Figs. 3–5. One patient with mild restriction had a contracture duration of 44 months. Two patients each with moderate restriction had contracture duration of 48 and 52 months whereas, 2 patients each with severe restriction had duration of 64 and 83 months. This indicates that the severity of the restrictive lung disease increases with the increase in duration of the contracture. The prolonged duration of contracture may lead to fibrous changes in the chest wall muscles leading to restrictive pattern in PFT.

Neil and Dissanaike reported a patient with reduced forced inspiratory volume following circumferential chest wall scar that improved after the contracture release surgery [8]. We observed a mean improvement of 0.17L in the FCV after contracture release surgery. Although the improvement in

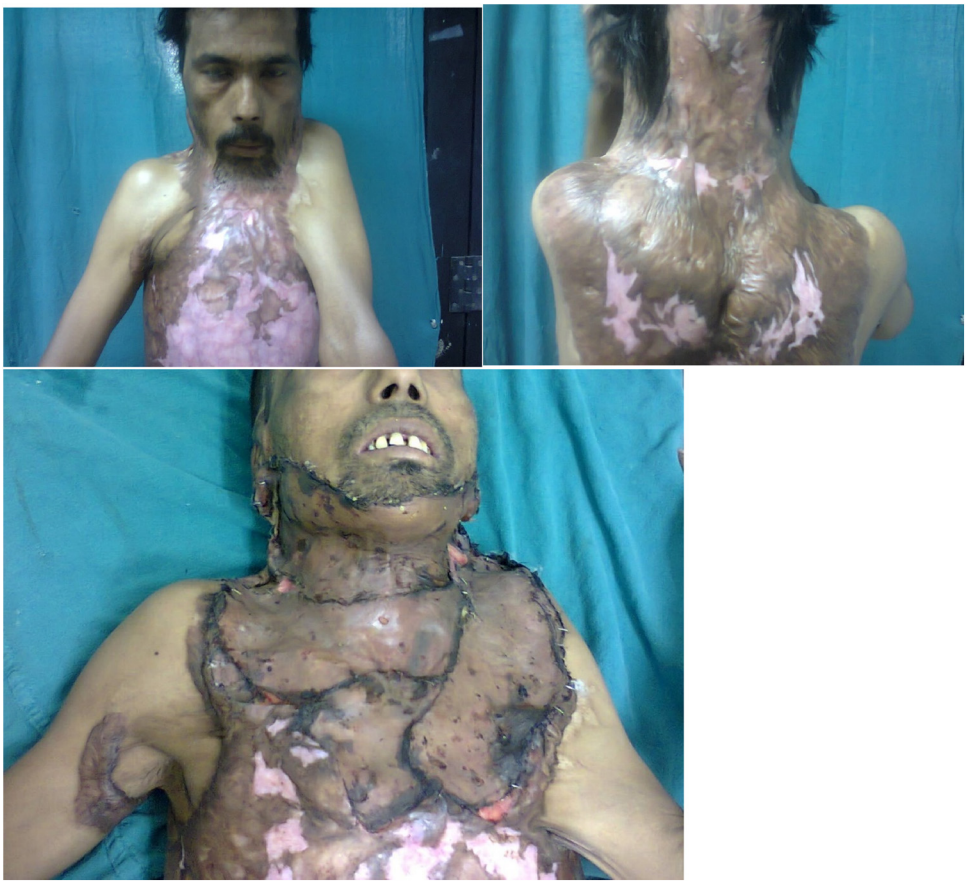

Fig. 3 – A 39 years old patient with burn contractures of chest wall and neck with involvement of >75% of the chest circumference had severe restrictive lung disease (FVC<50% of predicted normal). The patient had significant improvement in FVC after surgical release of the contractures.

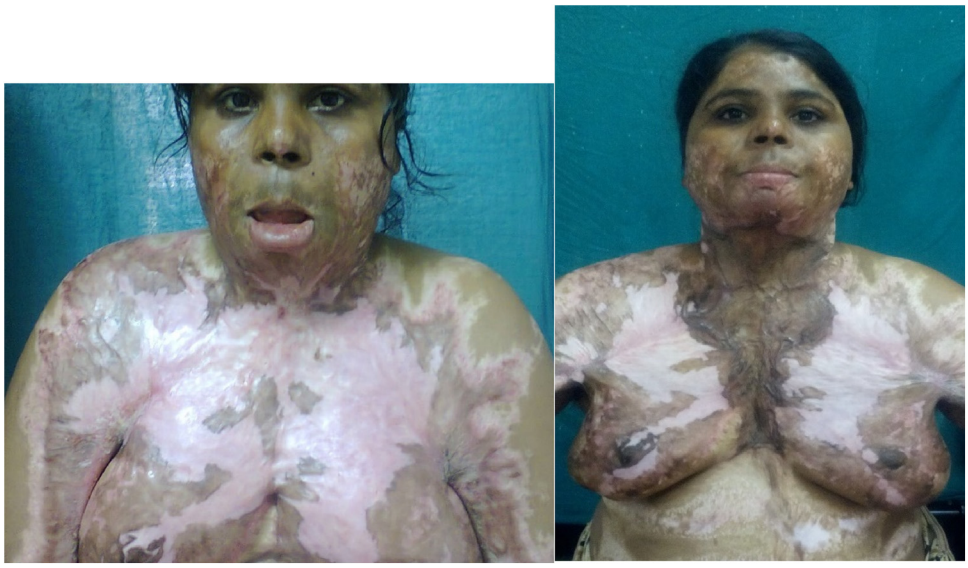

Fig. 4 – Preoperative and postoperative photographs of patient with burn scar and contracture involving >75% of chest wall. The patient had moderate restriction on PFT (FVC 50%–69% of predicted normal). Midline release of the chest wall contracture along with release of the neck contracture was performed.

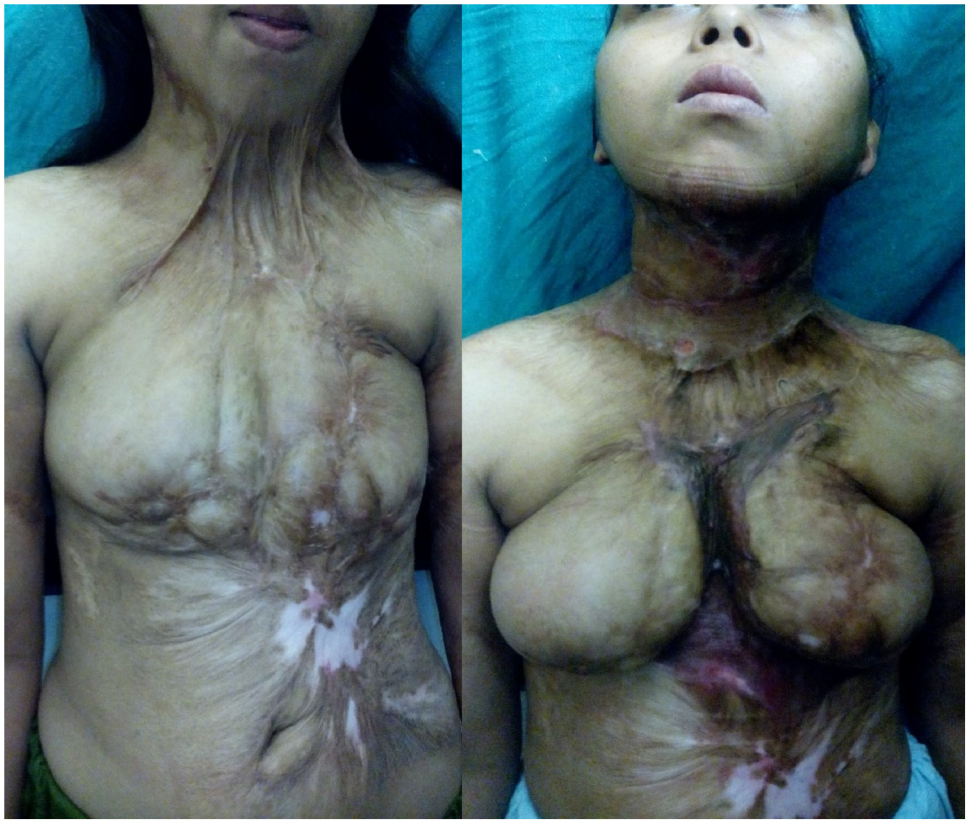

Fig. 5 – Preoperative and postoperative photographs of the patient with mild restriction on PFT (FVC 70%–79% of predicted normal).

FCV was significant (p=0.047), it was not sufficient enough to achieve the normal pattern; the patients still had restrictive lung disease. This is because long standing contractures produce irreversible fibrotic changes in the underlying musculoskeletal structures of the chest wall. Therefore, the release of the scar alone does not relieve the constriction completely. The effect of the surgical release of contracture might have been observed better if the follow-up period was longer. This may be the limitation of this study.

There was also a corresponding improvement in FEV1 values by a mean of 0.16L, which was statistically not significant (p=0.056). The negligible improvement may be due to the fact that these patients did not have any obstructive element in their PFTs before the contracture release surgery. None of our patients had a FEV1/FVC ratio of less than 80%. This indicates that obstructive lung disease does not develop in patients with chest wall contracture.

5. Conclusion

This study concludes that severe chest wall contractures involving >75% of the chest circumference may lead to a restrictive pattern in PFT. Circumferential Chest wall contracture does not lead to obstructive pattern abnormality in PFT. Likelihood of developing restriction pattern in PFT increases with the extent of involvement of the chest wall. Contractures of longer duration are more prone to cause restrictive lung disease. Also, the severity of restriction increases with the increase in duration of the contracture. It is unlikely that the patient will have any significant improvement in the restrictive pattern of PFT after contracture release.

Conflict of interest

None.

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