Evaluation of the Effect of Halo Gravity Traction on Lung Volume in Advanced and Severe Kyphoscoliosis Patients in Chest Radiography

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Abstract

Aim: To evaluate the effect of preoperative halo gravity traction on lung volume in patients with advanced and rigid kyphoscoliosis using planimetric measurements from chest radiography.

Method: Ten patients with a mean age of 20.5±0.9 with a diagnosis of severe and severe kyphoscoliosis who underwent halo gravity traction between 2019 and 2021 were included in our study. Direct chest radiographs taken before and after traction were analyzed retrospectively. In order to evaluate the effectiveness of traction, planimetric evaluations were made on radiographs.

Results: In the evaluation of radiological parameters, mean thoracic coronal cobb angle, lumbar cobb angle, thoracic kyphosis angle, lumbar lordosis angle, C1-S1 distance and lung volume before and after the procedure were 96.670°±8.4535°, 88,090°±4.5989°, 37.020°±11.5893°, 38.540°±11.1269°, 73.150°±7.0412°, 65.590°±7.3927°, 59.100°±9.5467°, 55.100°±9.0238°, It was 371.590mm± 64.2410mm, 408.330 mm±80.8229 mm and 967.730 mm^3±318.404 mm^3, 1155.180mm^3±332.868 mm^3. The decrease in thoracic kyphosis, lumbar lordosis, thoracic cobb and lumbar cobb angles and the increase in lung volume and distance between C1-S1 were statistically significant ($p<0.05$).

Conclusion: Traction application is a safe method for deformities. It is effective in correcting sagittal and coronal curvatures. It is a method that is effective in pulmonary functions as well as increasing the lung volume radiologically.

Keywords: Halo gravity traction, kyphoscoliosis, lung volüme, radiograph.

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Göğüs Radyografilerde İleri ve Sert Kifoskolyoz Hastalarında Kullanılan Halo Yer Çekimi Traksiyonunun Akciğer Hacmi Üzerindeki Etkisinin Değerlendirilmesi

Öz

Amaç: İleri ve sert kifoskolyozlarda cerrahi öncesi halo gravite traksiyonunun hastalarda göğüs radyografisinden planimetrik ölçümler kullanılarak akciğer hacmi üzerinde etkisini değerlendirmektir.

Yöntem: Çalışmaya, 2019-2021 yılları arasında halo yerçekimi traksiyon uygulaması yapılan ileri ve sert kifoskolyoz tanılı yaş ortalaması 20,5±0i9 olan 10 hasta dahil edildi. Traksiyon öncesi ve sonrası hastalara çekilen direkt akciğer grafileri geriye dönük incelendi. Traksiyonun etkinliğini değerlendirebilmek için grafiler üzerinden planimetrik değerlendirmelere tabi tutuldu.

Bulgular: Radyolojik parametrelerin değerlendirilmesinde işlem öncesi ve işlem sonrası ortalama torakal koronal cobb açısı, lomber cobb açısı, torakal kifoz açısı, lomber lordoz açısı, C1-S1 mesafesi ve akciğer volümü sırasıyla; 96,670°±8,4535°, 88,090°±4,5989°, 37,020°±11,5893°, 38,540°±11,1269°, 73,150°±7,0412°, 65,590°±7,3927°, 59,100°±9,5467°, 55,100°±9,0238°, 371,590mm±64,2410mm, 408,330mm±80,8229mm ve 967,730 mm^3±318,404 mm^3, 1155,180 mm^3±332,868 mm^3 idi. Torakal kifoz, lomber lordoz, torakal cobb ve lomber cobb açılarındaki azalma ile akciğer hacmi ve C1-S1 arasındaki mesafe artışı istatistiksel olarak anlamlıydı ($p < 0,05$).

Sonuç: Traksiyon uygulaması deformitelerde güvenli bir yöntemdir. Sagital ve koronal eğriliklerin düzelmesinde etkilidir. Pulmoner fonksiyonlar üzerine etkili olduğu gibi radyolojik olarak akciğer volümü üzerinde de artış yönünde fayda sağlayan bir yöntemdir.

Anahtar Sözcükler: Halo gravite traksiyonu, kifoskolyoz, akciğer volümü, radyografi.

Introduction

Surgical management of rigid and advanced kyphoscoliosis deformity always poses a great challenge for surgeons. Such progressive deformities can lead to neurological deficits. Cardiopulmonary functions and the quality of life of patients may also be affected. Preoperative pulmonary dysfunction, seen especially in such patients, furthermore increases the risk of mortality[1]. Halo gravity traction (HGT) is utilized to provide partial correction in advanced curvatures to alleviate such problems[2].

HGT is a technique that gradually corrects coronal and sagittal abnormalities in patients. With this correction, the spine lengthening and pulmonary functions can be enhanced[3]. The greatest benefit of the device to be implanted for the application of HGT is that it is simple to apply and does not necessitate prolonged bed rest in patients. Conversely, infections, which may arise with other traction methods, are uncommon[4]. Numerous studies have examined the impact of HGT administration on pulmonary function[5,6]. These studies primarily employed pulmonary function tests to examine lung functions[7].

To the best of our knowledge, there is no previous research on radiographic evaluation of lung capacity in medical literature. This study aimed to determine the effect of pre-surgery HGT treatment on lung volume in patients with advanced and rigid kyphoscoliosis, using planimetric measurements obtained from chest radiography.

Material and Methods

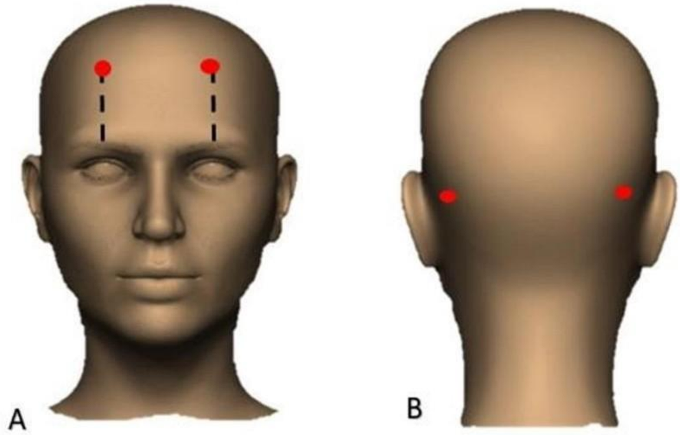
Patients with advanced and rigid kyphoscoliosis receiving preoperative HGT traction between January 2019 and December 2021 at a secondary healthcare institute were included in the study. Ethical board approval was obtained from the ethics committee of the same institution (Ethics committee protocol number: 27.07.20022/47). The study was conducted by the Declaration of Helsinki. Preoperative radiological images obtained before and after HGT application were retrospectively analyzed.

The criteria for HGT were as follows: (a) Rigid and advanced kyphoscoliosis with flexibility of less than 30° and a coronal cobb angle of more than 80°[8,9], (b) Sagittal cobb angle of more than 65°, (c) no advanced neurological deficit (d) severe impairment of pulmonary function tests defined as forced vital capacity percent (FVC%) ≤ 50%[10]. Patients with bone disease were excluded from HGT application.

HGT Application Procedure

Patients fasted four hours before the procedure that was performed under sedation and sterile conditions in the operating room. For sedation, 0.02 mg/kg of midazolam and 1 mcg/kg of fentanyl was used. The screw sites were re-sterilized with 10% povidone-iodine solution, and 1 ml of 2% lidocaine was used to provide local anesthesia. Two screws were placed on the mid-pupillary line on the anterior side, 3 cm proximal to the corrugator supercilii muscle, and the other two screws were placed bilaterally lateral to the mastoid on the posterior aspect. Screw locations are shown in Figure 1.

Figure 1. Halo screw entry points. A: Anterior screws, B: Posterior screws



Following the procedure, each patient underwent a cranial tomography to observe the relationship of screw to bone. Patients were rested for one day after the procedure. Traction was commenced using 5kg, with the traction weight increased 1-2 kg per day according to how well the patient tolerated the traction. Aim traction weight was calculated to be 30-50% of the patient's body weight. Neurological examination and evaluation of pain was conducted daily. To prevent loosening, screws were tightened every two days. Skin entry site of screws was dressed using 10% povidone iodine solution, daily.

Since the duration of traction was between 12-16 hours, the device was adjusted so that it could remain in traction in a mobilized and sitting position as well as in bed (Figure 2).

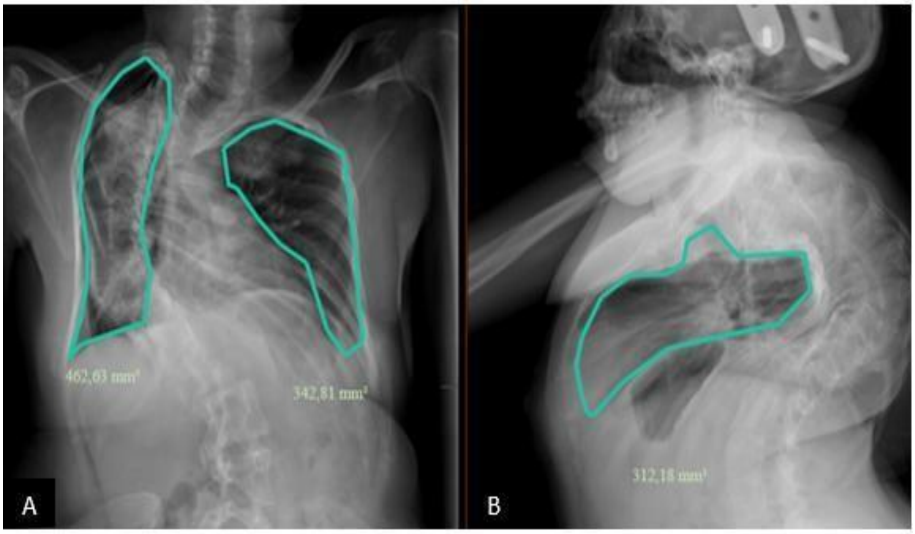
Figure 2. Application of halo gravity traction in A) standing, B) sitting, and C) supine position.

Traction was applied to the patients at all times except for when using the bathroom, toilet and during sleep. The mean total traction time was 30-35 days.

Radiological Evaluation

Scoliosis radiographs were taken before and after HGT. All radiographs were taken in the standing position. Thoracic kyphosis and lumbar lordosis angles in the sagittal plane, thoracic and lumbar cobb angles and C1-S1 distance in the coronal plane were measured using the "surgimap" clinical imaging tool (Nemaris Inc, New York, United States). To measure lung volumes before and after HGT, "surgimap" was used to manually mark first the outlines of the right lung and calculate its volume. The same procedure was conducted for the left lung. The lateral radiograph was then used to roughly mark the outlines of the left and right lung to calculate volume. The sum of these three volumes was used to calculate the total lung volume[11,12]. Sample surgimap measurements of one patient is shown in Figure 3.

Figure 3. Planimetric measurement using the "surgimap" programme. A. Right and left lung marking and measurement using posteroanterior chest radiograph and B) Lung marking and measurement using the lateral chest radiograph



Statistical Evaluation

Data is reported as mean, standard deviation, minimum and maximum. Wilcoxon Signed Ranks test was used for comparison of data. A blinded statistician evaluated data and performed statistical analysis. Statistical significance was accepted as $p<0.05$.

Results

Three males and seven females were included in the study. The average age of patients was 20.5±0.9 years. Pre and post HGT thoracal coronal cobb angle, lumbar cobb angle, thoracic kyphosis angle, lumbar lordosis angle, C1-S1 distance and total lung volumes are shown in Table 1.

Table 1. Minimum, maximum, mean and standard deviation for study measurements.

	(n)	**Min**	**Max**	**Mean**	**Z**	**Asymp. Sig. (2-tailed)**
Pre HGT TCA	10	83.5°	111.4°	96.67°±8.45°	- 2,803^{b}	p <0.05
Post HGT TCA	10	79.1°	97.4°	88.09°±4.60°		
Pre HGT LCA	10	19.9°	59.1°	37.02°±11.59°	-,408^{c}	p=0.683
Post HGT LCA	10	20,4°	59.9°	38.54°±11.13°		
Pre HGT TKA	10	61.1°	86.5°	73.15°±7.04°	- 2,805^{b}	p<0.05

Post HGT TKA	10	54.4°	79.5°	65.59°±7.39°		
Pre HGT LLA	10	42.6°	68.4°	59.10°±9.55°	- 2,606[b]	p<0.05
Post HGT LLA	10	37.1°	64.1°	55.10°±9.02°		
Pre HGT C1-S1 distance (cm)	10	268.1	472.8	371.59±64.24	- 2,805[c]	p<0.05
Post HGT C1-S1 distance (cm)	10	281.1	575.1	408.33±80.82		
Pre HGT LV (mm^3)	10	449.3	1395.1	967.73±318.40	- 2,803[c]	p<0.05
Post HGT LV (mm^3)	10	568.1	1614.1	1155.18±332.87		

sHGT: Halo gravity traction, TCA: thoracic cobb's angle, LCA: lumbar cobb's angle, C1-S1 distance: cervical 1-sacral 1 distance, centimeter (cm), TKA: Thoracic kyphosis angle, LLA: Lumbar lordosis angle, LV: Lung volüme, cubic millimeter (mm^3). a. Wilcoxon Signed Ranks Test, b. based on positive ranks, c. based on negative ranks.

The decrease in thoracic kyphosis, lumbar lordosis, thoracic cobb and lumbar cobb angles and the increase in distance between C1-S1 were found to be statistically significant ($p<0.05$). In addition to the changes in sagittal and coronal parameters, the increases in lung volume was also statistically significant ($p<0.05$).

Discussion

Surgical correction of rigid and advanced kyphoscoliosis abnormalities is challenging and associated with significant mortality and morbidity. Neuronal injury and possible progressive neurological impairment including plegia can occur intra or post-operatively. The likelihood of pulmonary dysfunction is not only substantial in patients with rigid and severe kyphoscoliosis deformity, but it is also a significant issue that complicates perioperative surgical planning[13].

In patients with such deformities, pulmonary function tests are generally used to determine pulmonary function. The consensus in the literature is that HGT application is effective in improving vital capacity, forced vital capacity (FVC), forced expiratory volume in the first second (FEV1) and peak expiratory flow rate (PEF)[14]. However, to the best of our knowledge, the radiological evaluation of the effect of HGT application on lung volume in patients with severe and advanced kyphoscoliosis does not exist. Our study is therefore novel in this respect.

Computed tomography is the best radiological imaging method for evaluating lung volume. Direct radiographs containing fewer X-ray doses can also be used to evaluate lung volume[15]. The direct chest radiograph is a low-dose, fast and inexpensive option for the early detection and follow-up of respiratory tract diseases. Chest radiographs can evaluate lung volume in patients with acute or chronic lung injury[16]. In this study, we aimed to measure the effect of HGT on lung volumes as calculated using chest radiography in patients with rigid and advanced kyphoscoliosis. Lung volume was measured as the area in our study. Our data shows that HGT has a positive effect on lung volume. We believe that traction is responsible for the improvement of the thoracic cobb angle and the reduction of thoracic kyphosis. Some studies suggest that the association between pulmonary dysfunction disorder and the thoracic and thoracolumbar curvatures are related to their extent[17]. These curvatures, especially upper thoracic curvatures lead to overall decreased lung volumes causing, therefore, lower inspiratory and expiratory volumes when compared to the normal population. It is emphasized that the positive effect on pulmonary function tests observed after traction is related to the improvement of scoliosis angles in the sagittal and coronal planes[18,19]. Our results correlate with this information. The radiological evaluation also revealed that high thoracic and lumbar cobb angles seen before traction decreased after HGT application. With the decreases, C1-S1 lengths on the coronal planes also increased. These findings were also similar to those previously reported in literature[20,21].

Our study is limited by the small number of patients. Larger studies are required to reach more objective conclusions regarding the usefulness of radiographic evaluations of lung volume and the effect of HGT traction on lung volume.

Conclusion

In severe deformities, HGT administration can greatly enhance patient tolerance to surgery. HGT is safer than other traction methods and has a reduced complication rate since traction is gradually applied and the body's weight is utilized as a counterforce. It can improve scoliosis angles and decrease postoperative pulmonary problems. Its effects on improving pulmonary function tests can be observed radiologically on chest radiographs. In addition to pulmonary function tests, chest radiographs can be used to give an insight into pulmonary functions before surgery.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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