Functional Respiratory Changes in Patients with Chest Wall Deformities Secondary to Autologous Costal Cartilage Harvest for Auricle Reconstruction


1Departments of Plastic and Reconstructive surgery, Hospital General Dr. Manuel Gea González, Mexico City, Mexico
2Biotechnology Laboratory, National Burns Center, National Institute of Rehabilitation Luis Guillermo Ibarra Ibarra (INR LGII), Mexico
3National Cancer Institute, Mexico
4National Institute of Respiratory Diseases, Mexico
5Research, National Institute of Rehabilitation Luis Guillermo Ibarra Ibarra, Mexico
6Hospital ABC, Mexico
7Conacyt-National Institute of Rehabilitation Luis Guillermo Ibarra Ibarra, Mexico

Abstract

Background: The gold standard for auricle reconstruction is currently performed with autologous costal cartilage. This process is done at about nine years of age, but it leads to thoracic deformity, reported in up to 70% of the patients using a computed tomography (CT) scanner.

Objective: The present study aims to determine if this deformity has functional implications for the patients.

Methods: 54 patients were clinically evaluated and subjected to spirometry at least one year after the surgery.

Results: Four cases had moderate pulmonary restriction, while seven had mild lung restriction. A total of 20.3% of the patients showed pulmonary restriction. The new results are particularly crucial for patients with preoperative (pre-op) ventilatory disease.

Conclusion: In patients with thoracic deformity diagnosed by clinical exploration, spirometric abnormalities occur in up to 20.3%; when stratifying the risk by gender, the risk is only significant for women older than 15 years old.

Keywords: Auricle reconstruction, Respiratory function alterations, Thoracic deformity, Autologous auricle reconstruction sequelae, Microtia.

Introduction

Microtia (small ear) is a congenital deformity secondary to an alteration during embryonic development characterized by the partially or entirely underdeveloped pinna. The earliest reports of auricle reconstruction are described in the Sushruta Samhita, an ancient text, 900 BC. In 1930, Pierce reported a post-traumatic repair using costal cartilage. The previous findings paved the way for Tanzer, who pioneered modern costal cartilage reconstruction. Since then, the sixth to the tenth costal cartilages have been used in auricle reconstruction techniques. The pathophysiology of post-operative chest deformities can be explained in two ways, the first...
one being the age at which cartilage resection is performed. Neter
scher found that the greatest thoracic cage growth occurs during the
first four years of life, with a second peak between 12 and 18
years of age. This approach goes hand in hand with the mechanical
factor proposed by Ohara, in which ribs with resected cartilage tend
to curve inwards due to the effect of muscular force since they no
longer have cartilaginous support. The second alternative shows
that another important factor is the number of costal cartilages re-
sected. Resection of the sixth costal cartilage produced deformity in 100% of the cases. However, the above procedure conducted in
the seventh cartilage affected only 47.4 % of the patients. Also, the
reconstruction of the auricular framework is generally carried out
before the age of 10. Early reports recommend that it be carried out
before the age range of 5-6 years. The recommendations have in-
corporated the psychosocial factors (i.e., school entry age) and the
intervention at two years of age.

Besides, the chest deformity resulting from cartilage resection
can affect the patient’s respiratory function. Spirometry has been
used to evaluate respiratory function. This test shows the muscular
effort of the thorax dynamically. It also indicates the interdepen-
dence of the alveoli with the retraction of the chest and lungs. The
functional exploration of the respiratory system is an objective
method to assess pulmonary function and quantify the degree of
impairment caused by respiratory diseases. Forced spirometry is
the most commonly performed functional test, and it can be car-
rried out in patients as young as 5-6 years of age. The analysis of
the forced expiratory volume in the first second (FEV1) allows us to
classify the functional alteration quantitatively as mild, moderate,
severe, and very severe. The analysis of FEV1, Forced Vital Capacity
(FVC), and the ratio of both volumes (FEV1/FVC) allow to qualifi-
catively classification pulmonary disorders in 3 different patterns:
obstructive, restrictive, and mixed.

One of the first studies investigating the chondrogenic poten-
tial of the perichondrium discussed that the freed perichondrium
could generate cartilage and that the new cartilage proliferates
from the undersurface of the perichondrium. Tanzer followed up
postoperative patients aged 6 to 19; they found that chest deformi-
y occurred in 50% of the patients, associated with reconstruction
carried out at an early age and mechanical factors that increase
the thoracic cage’s loss of stability. Ever since, efforts have been
undertaken to reduce this complication by adjusting the surgical
technique, such as sub-perichondria resection of the cartilage or
saturating the periostium after resection. However, the results have
not been satisfactory. The study’s main objective is to assess
respiratory function in patients with chest deformity secondary
to costal cartilage harvest for auricle reconstruction. Also, identify
which respiratory alteration is found in these patients and a cor-
relation between body mass index (BMI) and functional alterations.

Methods
Study design

This research is a descriptive, open, observational, prospec-
tive, and cross-sectional study. Patients diagnosed with microtia by
the Plastic and Reconstructive Surgery® service at Dr. Manuel Gea
González General Hospital have been included. Auricle reconstruc-
tion with rib cartilage was conducted by this service (at least a year
before the study), with a clinical report of chest deformity and free
acceptance of participation under informed consent and assent let-
ters. In addition, patients with any congenital chest deformity, lung
disease diagnosed before surgery, and patients who smoke and
with a diagnosis of obesity (BMI>30) were excluded.

Postoperative patients with seventh to ninth costal cartilage
harvest were analyzed in all cases. A clinical and spirometric con-
rol evaluation was performed at least one year after surgery. Sex,
age, evident clinical deformity, and thoracic asymmetry were also
documented.

The clinical evaluation was performed by the Plastic and Re-
constructive Surgery service to detect asymmetry during respira-
tory movements. It included the “thumb test” (the physician places
both hands around the patient’s back from the anterior axillary line
to an equidistant position at spine level). During deep inspiration,
a lateral displacement of the thumbs occurs, noting the difference
between both sides, if applicable. A direct medical history was tak-
en to detect pre-existing conditions such as congenital anomalies,
trauma, and previous reconstructive procedures not associated
with auricle reconstruction that might occur with chest deformi-
y. A pulmonologist performed the spirometric evaluation with a
third-generation Henan Medical Spirobank II spirometer (Miami,
Florida, USA). The evaluator was not informed of the results of the
plastic surgeon’s clinical evaluations carried out previously.

Statistical analysis

A bivariate analysis was conducted to compare means after
checking the normality or non-normality of the distributions with
Kolmogorov-Smirnov’s Z. Student’s t-test or Mann-Whitney U per-
formed it. The comparison of proportions was conducted with a
chi-square test. The intensity of the associations was calculated as
relative risk with 95% confidence intervals. The Mantel-Haenszel
statistic was applied to compare risks by strata. Correlations were
estimated with Pearson’s r statistic or, when appropriate, Spear-
man’s p. The receiver operating characteristic (ROC) curve was
used to estimate the best cut-off point for a continuous variable that
significantly differentiated the pulmonary restriction groups. The
multivariate analysis for mean comparison was performed with a
two-factor analysis of variance adjusted with analysis of covari-
ce. The data were processed with the SPSS 17.0 package for Win-
dows. In all statistical hypotheses, a p<0.05 was assumed to reject
the null hypotheses.

Specialized terminology

Clinical deformity: Defect observed in the thoracic contour
evident through inspection by the evaluating physician (certified
plastic and reconstructive surgeon).

Inspiratory asymmetry: Asymmetric expansion observed in
the costal cage during the inspiration.
Results

Fifty-four patients were evaluated; 26 (48.1%) were female, and 28 (51.9%) male. The average age was 15.5±6.1 years old (ranged from 10 to 42). Because of the wide age margin, the distribution did not resemble the Gauss curve verified with the Kolmogorov-Smirnov test with Z= 1.36 (p=0.04), as seen in Figure 1. The average body mass index was 20.8±3.3 (ranged at 13.4-28.4) with a normal distribution (Kolmogorov-Smirnov Z of 0.65, p = 0.79).

The collapsed incidence of pulmonary restriction in ordinal to nominal as moderate/mild versus no restriction was 20.4% and associated with age. As shown in Table 1, the gender distribution is not significantly different (p=0.63 according to square Chi). The body mass index (BMI) neither was associated with pulmonary restriction (p=0.77 according to Student’s t-test); instead, the average age in pulmonary restriction cases is significantly higher (16.4±3.2 years) when compared with those without restriction (15.3±6.7 years) with p=0.05 according to no parametric U of Mann.

Table 1: Comparative characteristics of patients with versus without pulmonary restriction with thoracic deformity secondary to costal cartilage resection for auricle reconstruction.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Pulmonary Restriction</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moderate/Mild (n=11)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Without restriction (n=43)</td>
<td>0.63</td>
</tr>
<tr>
<td>Female</td>
<td>6 (54.5%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>5 (45.5%)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>16.4±3.2</td>
<td>0.05</td>
</tr>
<tr>
<td>BMI</td>
<td>20.6±2.4</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>20.8±3.3</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 shows the ROC curve that identifies the best cut point of the age to separate the cases of pulmonary restriction. The best cut point of the age was 15 years old (ROC curve area 0.687±0.08 with p=0.05). In figure 1 the ROC curve of the susceptibility versus the specificity. The Ties produce the diagonal segments. The hypothesis test variable result indicates that age has at least one tie-up between the real and real-state negative groups. The minor cut value is the hypothesis test value observed maximum plus one. The rest of the cut values are the media of two hypothesis test values observed ordered and consecutive. The age collapsed into two subgroups, namely, 16-42 and 10-15-year-old age group. The older age group showed more pulmonary restriction risk. A pulmonary restriction secondary to costal cartilage resection in 36.4% in the older than 15 years old group patients versus only 9.4% in the 10-15 years old group was noted.

The relative risk was 3.8 (confidence interval (CI)=95% of 1.1-13.0, p=0.01). This result indicates 3.8 more pulmonary restriction risk in patients older than 15 years old than the 10-15-year-old age group. The risk stratification by age showed a significant difference only for females older than 15 years. This group also presented a pulmonary restriction relative risk of 6.8 (p=0.01). Conversely, the risk of the male stratum from the same age group was 2.3 (p=0.30) and was not statistically significant. Furthermore, the value obtained from the Mantel-Haenszel chi-square test (4.1, p=0.04) confirmed that pulmonary restriction risks are statistically different between women and men. The two-way analysis of variance (ANOVA) with the covariance analysis carried out to adjust the BMI age is summarized in Table 2 and depicted in Figure 2. The covariable was 15.5 years old. As seen, the average BMI in the cases of pulmonary restriction between females and males is equal (p=0.66). On the other hand, in the cases without pulmonary restriction, the BMI of the male group is significantly higher than the female group (p=0.02). When comparing the groups with or without pulmonary restriction, the mean BMI value indicates no significant differences for either the women’s (p=0.43) or men’s groups (p=0.21).

Table 2: Correlation of BMI with sex and cases of pulmonary restriction.

<table>
<thead>
<tr>
<th>CRF-RP</th>
<th>Sex</th>
<th>Media</th>
<th>Typical error</th>
<th>Confidence interval 95% Lower limit</th>
<th>Upper limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate/Mild</td>
<td>Female</td>
<td>20.86</td>
<td>1.31</td>
<td>18.22</td>
<td>23.49</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>20.01</td>
<td>1.43</td>
<td>17.14</td>
<td>22.88</td>
</tr>
<tr>
<td>Without</td>
<td>Female</td>
<td>19.68</td>
<td>0.72</td>
<td>18.24</td>
<td>21.11</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>21.99</td>
<td>0.67</td>
<td>20.65</td>
<td>23.32</td>
</tr>
</tbody>
</table>

Figure 2: Shows the ROC curve that identifies the best cut point of the age to separate the cases of pulmonary restriction.
The pulmonary interaction restriction assigned to the variable *sex shows a p=0.15, which tends to be significant. As seen in Figure 2, the female gender (as being with more risk) has a higher BMI (20.86) in pulmonary restriction cases compared with no pulmonary restriction ones (19.68). By contrast, the male gender with pulmonary restriction revealed lower BMI media (20.01) than those without restriction (21.99). Nevertheless, none of the statistical hypotheses tests are significant, confirming that the true associated factor to pulmonary restriction risk is exhibited for the females older than the 15-year-old age group.

Discussion

The thoracic deformity is one of the potential complications in treating patients undergoing costal cartilage harvesting for any purpose, either reconstructive or aesthetic. Earlier works have reported complications after harvesting costal cartilage with short-term follow-up.

In patients with microtia, the thoracic deformity after taking the costal cartilage has been underestimated, and there are currently few reports in the current literature based on long-term follow-up. Thompson et al. published a retrospective study that reported chest deformity in 33% of the cases where cartilage was taken at the ages of 2 to 3 compared to 8% when it was removed by age covering 6-12. Ohara confirmed chest deformity of 63.6% and 10% for cartilage removal before and after 1-year-old patients, respectively. The above results demonstrated a correlation between age and the prevalence of chest deformity, where chest deformity was seen more in younger patients. Kawane and Nagata reported that the most critical factor in predicting postoperative chest deformity is not through the cartilage but via the technique with which it is removed. They suggested that preserving costal perichondrium and the subsequent adherence of the leftover fragments may reduce this complication.

The respiratory alterations found in congenital chest deformities (i.e., scoliosis, rib fusion) are well known and have already been studied. However, there is no information regarding these alterations after costal-cartilage harvest to the best of our knowledge. For this reason, in our most recent study, we aimed to detect thoracic deformities secondary to costochondral harvesting using both imaging (CT scan) and clinical analysis. We found that taking three or more cartilages caused deformity in up to 70% of the patients, but only 30% were clinically evident. The anteroposterior thoracic diameter is the most affected section. In addition, the effect of the muscular insertion causes something that we call “pseudo-gynecomastia.” We also found out that specific bone alterations are resulting from the cartilage resection pattern. The degrees of deformity helped us classify the patients to set a precedent and carry out future association measures.

Two essential questions are: Would these deformities affect respiratory function, and could it be detected through spirometry? Should the diagnosis of alterations in ventilatory mechanics be considered beforehand in patients undergoing auricle reconstruction with rib cartilage harvest to consider the possibility of worsening ventilatory function?

Acknowledgments

Lic. Mariana Rodríguez Velasquillo for her invaluable help with the edition of the manuscript. Student Naomi Mariana Martínez Enriquez for the data analysis.
Funding

None.

Conflicts of Interest

Author declares that there is no conflict of interest.

References