Is neck tilt and shoulder imbalance the same phenomenon?
A prospective analysis of 89 adolescent idiopathic scoliosis patients (Lenke type 1 and 2)

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Abstract
Purpose To introduce a new clinical neck tilt grading and to investigate clinically and radiologically whether neck tilt and shoulder imbalance is the same phenomenon in AIS patients.
Methods 89 AIS Lenke 1 and 2 cases were assessed prospectively using the new clinical neck tilt grading. Shoulder imbalance and neck tilt were correlated with coronal height difference (CHD), clavicle/rib intersection distance (CRID), clavicle angle (CA), radiographic shoulder height (RSH), T1 tilt and cervical axis.
Results Mean age was 17.2 ± 3.8 years old. 66.3 % were Lenke type 1 and 33.7 % were type 2 curves. Strong intraobserver (0.79) and interobserver (0.75) agreement of the clinical neck tilt grading was noted. No significant correlation was observed between clinical neck tilt and shoulder imbalance (0.936). 56.3 % of grade 3 neck tilt, 50.0 % grade 2 neck tilt patients had grade 0 shoulder imbalance. In patients with grade 2 shoulder imbalance, 42.9 % had grade 0, 35.7 % grade 1, 14.3 % grade 2 and only 7.1 % had grade 3 neck tilt. CHD, CRID, CA and RSH correlated with shoulder imbalance. T1 tilt and cervical axis measurements correlated with neck tilt.
Conclusions In conclusion, neck tilt is distinct from shoulder imbalance. Clinical neck tilt has poor correlation with clinical shoulder imbalance. Clinical neck tilt grading correlated with cervical axis and T1 tilt whereas clinical shoulder grading correlated with CHD, RSH, CRID and CA.

Keywords Neck tilt · Shoulder imbalance · Adolescent idiopathic scoliosis · Lenke 1 · Lenke 2

Introduction
Scoliosis is a three-dimensional deformity of the spine as the deformity in scoliosis involves axial rotation, sagittal plane deformity with thoracic hypokyphosis and translation of the spine in the coronal plane [1]. Surgical correction is aimed at fusing the least number of motion segments to achieve a good trunk, shoulder and neck balance.

Pedicle screws have been widely used for scoliosis surgery [2–6]. The strength of pedicle screws has enabled shorter fusion with more correction [7, 8]. However, over correction of the main thoracic (MT) curve may give rise to shoulder imbalance [9, 10]. This phenomenon is due to failure of the proximal curve to compensate in Lenke type 2 curves as well as in a selective group of Lenke type 1 curve.

The incidence of shoulder imbalance has been reported to be between 23 and 32 % [11–13]. Shoulder imbalance is associated with T1 tilt, pre-operative shoulder height, first rib inclination, coronal height difference, clavicle angle, radiological shoulder height, clavicle/rib intersection distance and pre-operative proximal thoracic (PT) curve [14–16].
Neck tilt phenomenon in scoliosis has not been well documented. However, this phenomenon is observed commonly in pre-operative patients as well as post-operative patients. There is currently no available English literature describing grading of neck tilt. In addition, patients with shoulder imbalance may or may not have neck imbalance. Therefore, the aim of this study is to investigate the relationship between 'shoulder balance' and 'neck tilt' radiologically as well as clinically.

Materials and methods

This is a prospective clinical-radiological study, which is carried out, in a single institution from December 2011 to June 2012. Approval from the ethics committee was obtained. Inclusion criteria for this study are as stated below:

1. Lenke 1 and Lenke 2 adolescent idiopathic scoliosis (AIS) patients.
2. Pre-operative patients who were awaiting surgery and patients were treated with bracing/observation.
3. Patients who had undergone posterior spinal fusion with pedicle screw fixation.

Exclusion criteria for this study include:

1. Patients with associated deformity or pathology of the cervical spine.
2. Patients who had spinal fusion extending to the cervical spine.
3. Patients who had undergone revision scoliosis correction.

This study consists of two parts:

(a) Part 1:

(a) a neck tilt classification is introduced. The interobserver and intraobserver reliability of this neck tilt classification is verified.

(b) Part 2:

(a) correlation between clinical neck tilt and clinical shoulder imbalance was evaluated.

(b) Radiological parameters that assess shoulder and neck balance were correlated with the clinical neck tilt and shoulder grading.

Part 1 study:

This part involved two observers (orthopedic surgeons) who are not the authors of this study. The observers assessed photographs of 30 AIS patients (50 photographs) and instruction on the clinical neck tilt grading was given. Each patient underwent three photographs (one in neutral relaxed position, one with active contraction of the neck muscle to the right, and one with active contraction of the neck muscle to the left). The photographs were taken with patient standing in front of a grid (large squares measured 10 cm × 10 cm and small squares measured 2.5 cm × 2.5 cm). The shoulder and the neck of the patients were adequately exposed. Grading of the photographs was repeated in a random fashion 4 weeks later to assess the intraobserver reliability. The new clinical neck tilt grading is shown in Fig. 1 and described below:

Grade 0: no neck tilt.
Grade 1: patient has correctable neck tilt with active neck muscle contraction. Trapezius muscle height is equal.
Grade 2: patient has neck tilt, not correctable. Trapezius muscle height difference is <1 cm.
Grade 3: patient has neck tilt, not correctable. Trapezius muscle height difference is >1 cm.

Trapezius muscle height is determined by an intersecting point between a line drawn along the neck with the outline of the trapezius (Fig. 1).

Part 2 study:

89 patients were recruited using the inclusion and exclusion criteria listed above. Clinical photograph for assessment of the clinical neck tilt and shoulder grading was obtained using a similar method as described.

Fig. 1 New clinical neck tilt grading

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