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

Mun Keong Kwan1 · Kai Ann Wong1 · Chee Kean Lee1 · Chris Yin Wei Chun1

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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 coracoid height difference (CHD), clavicle/rib intersection distance (CRID), clavicle angle (CA), radiographic shoulder height (RSH), T1 tilt and cervical axis.
Results Mean age was 172.3 ± 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, 56.0 % of 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 fixing 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 for 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, coracoid height difference, clavicle angle, radiological shoulder height, clavicle/rib intersection distance and pre-operative proximal thoracic (PT) curve [14–16].

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