Boyden’s triad in the left lung: an interesting phenomenon

Min Zhang†, Wei-Jie Sun†, Qing-Chen Wu and Ming-Jian Ge*

Department of Cardiothoracic Surgery, The First Affiliated Hospital of Chongqing Medical University, Chongqing, China

* Corresponding author. Department of Cardiothoracic Surgery, The First Affiliated Hospital of Chongqing Medical University, Chongqing 400016, China. Tel: 86 023 89011010; e-mail: 253616309@qq.com (M.-J. Ge).

Received 8 January 2022; received in revised form 21 February 2022; accepted 16 March 2022

Abstract

OBJECTIVES: Boyden’s triad of the right lung was first proposed in 2021. Here, we report 5 cases of this malformation found in the left lung.

METHODS: A total of 5280 patients with pulmonary lesions underwent three-dimensional computed tomography bronchography and angiography between January 2019 and January 2021, prior to surgery; 5 cases of this malformation were identified in the left lung. Bronchovascular patterns were analysed in each patient.

RESULTS: The incidence rate of Boyden’s triad in the left lung was 0.1%. This malformation was further divided into B3 on B4+5 type and B3 on B4 type. In B3 on B4+5 type, B3 was shifted downwards on the common trunk of B4+5, and A3 arose from the common trunk of A4+5 running alongside B3. In B3 on B4 type, B3 was shifted downwards on B4. A4 and A5 appeared separately. A3 arose from A4, running alongside B3; A5 arose from the common trunk of A8–10, and there was also an extraordinary ‘posterior vein’ (V. post): V1+2c. The incidence of V. post was 0.17%. An additional ‘fissure’ lies longitudinally between S1+2 and S3+4+5, nearly perpendicular to the oblique fissure, dividing the upper lobe into ‘two lobes’.

†These authors contributed equally to this article and should be considered as co-first authors.

© The Author(s) 2022. Published by Oxford University Press on behalf of the European Association for Cardio-Thoracic Surgery. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial License (https://creativecommons.org/licenses/by-nc/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited. For commercial re-use, please contact journals.permissions@oup.com
CONCLUSIONS: The B\textsuperscript{3} downwards-shifting malformation can be found on both lungs, and this is the first description of Boyden’s triad in the left lung; it appears to be much rarer than that in the right lung, with some accompanying unique variations.

Keywords: Boyden’s triad • B3 downward-shifting • Segmentectomy

| ABBREVIATIONS |
|----------------|
| 3D-CTBA        | Three-dimensional computed tomography bronchography and angiography |
| UVPBI          | Upper lobe vein posterior to the bronchus intermedius |

INTRODUCTION

The branching patterns of the pulmonary bronchus and vessels vary significantly among patients. Preoperative identification of the individual anatomy is essential to ensure an accurate and safe surgery. Three-dimensional computed tomography bronchography and angiography (3D-CTBA) is a minimally invasive and simple method of delineating the pulmonary vessels for lung resection than conventional pulmonary angiography. Three-dimensional CTBA is a useful tool for chest surgeons to preoperatively analyse pulmonary anatomy. Anatomic segmentectomy is frequently indicated for non-solid tumours with ground-glass opacity [1, 2]. However, both bronchial and vascular structures vary greatly at the segmental level and segmentectomy is technically more challenging than other surgical options, such as lobectomy. Ultimately, a comprehensive preoperative analysis of the patient’s anatomy is important for providing optimal treatment.

In 1950, Boyden reported a gross anomaly involving the right upper and middle lobes, in which the middle lobe bronchus gave rise to the anterior segment of the upper lobe bronchus as well as to its own segments. This is the first description of ‘B3 downwards-shifting malformation’ [3]. With the help of 3D-CTBA, Zhang et al. [4] identified 14 cases of right-sided B\textsuperscript{3} downwards-shifting malformations in 2356 patients and concluded that its incidence was 0.6%. This malformation, together with 2 other coexisting variations, was named ‘Boyden’s triad’. Since the introduction of this new concept, several concerns and disputes have arisen. One of the key concerns has been the possibility of Boyden’s triad in the left lung, since it has been identified in the right. Here, we report 5 cases of B\textsuperscript{3} downwards-shifting malformation in the left lung, introducing the concept of a left-sided Boyden’s triad.

METHODS

Ethics statement

The study was approved by the ethics committee of the first affiliated hospital of Chongqing Medical University (2020-206). The need for patient consent was waived because of the retrospective nature of the study.

Patient characters

All the patients with pulmonary lesions underwent preoperative 3D-CTBA from January 2019 to 2021. For every patient, computed tomography pulmonary angiogram was performed. Three-dimensional CTBA reconstruction was performed using the Mimics software (Belgium).

Variations in bronchovascular pattern and parenchymal division

Like the triad on the right, Boyden’s triad on the left includes variations in 3 aspects: vascular anatomy, bronchial anatomy and parenchymal division. It was therefore defined as follows: (i) B\textsuperscript{3} shifted downwards to arise from the bronchus of the lingual segment; (ii) accordingly, A\textsuperscript{3} arose from the artery of the lingual segment, and the upper lobe vein (V\textsuperscript{1+2c}) drained posterior to the bronchus into the inferior pulmonary vein; and (iii) an additional ‘fissure’ dividing the upper lobe into ‘two lobes’. Because similar variations in the right lung were named ‘Boyden’s triad’, we likewise defined this anomaly as ‘Boyden’s triad (left)’.

RESULTS

A total of 5280 patients were included and 5 cases of malformation were identified, for an overall incidence of 0.1%. There are 4 women and 1 man in the 5 patients. The mean age was 51 years. Boyden’s triad (left) was assessed and divided into B\textsuperscript{3} on B\textsuperscript{4+5} type, and B\textsuperscript{3} on B\textsuperscript{4} type. In B\textsuperscript{3} on B\textsuperscript{4+5} type (2/5), B\textsuperscript{3} is shifted downwards on the common trunk of B\textsuperscript{4+5}. In B\textsuperscript{3} on B\textsuperscript{4} type (3/5), B\textsuperscript{3} is shifted downwards on B\textsuperscript{4} (Fig. 1).

Regarding arterial anatomy in B\textsuperscript{3} on B\textsuperscript{4+5} type, A\textsuperscript{3} arises from the common trunk of A\textsuperscript{4+5}, running alongside B\textsuperscript{3} (Fig. 2B). In B\textsuperscript{3} on B\textsuperscript{4} type, A\textsuperscript{3} and A\textsuperscript{2} arise separately. A\textsuperscript{3} arises from A\textsuperscript{8}, running alongside B\textsuperscript{3}; A\textsuperscript{5} arises from the common trunk of A\textsuperscript{8-10}, after A\textsuperscript{8} (Fig. 2C). The vessel details are listed in Table 1. The incidence of B\textsuperscript{3} arising from B\textsuperscript{8} was 40% (2/5) and the incidence of B\textsuperscript{3} arising from B\textsuperscript{4+5} was 60% (3/5). The incidence of A\textsuperscript{3} arising from A\textsuperscript{3} was 60% (3/5) and the incidence of A\textsuperscript{5} arising from A\textsuperscript{4+5} was 40% (2/5). The incidence of the common trunk in A\textsuperscript{4+5} was 40% (2/5). The incidence of A\textsuperscript{5} arising from A\textsuperscript{8-10} was 60% (3/5) (Table 1).

The venous structures were more complicated. In the nomenclature proposed in 2020 [5], there were 2 concepts regarding the central vein and anterior vein (v. ant). In Boyden’s triad (left), however, there is an extraordinary ‘posterior vein’ (V. post): V\textsuperscript{1+2c}. It runs posterior to the bronchus, draining S\textsuperscript{1+2c} in the upper lobe, and finally merges into the inferior pulmonary vein (Fig. 3). The incidence of V\textsuperscript{1+2a+b}, V\textsuperscript{1+2c} and V\textsuperscript{1+2d} was 100% (5/5) (Table 1). A similar variation on the right side is described as the upper lobe vein posterior to the bronchus intermedius (UVPI). Nine cases of V. post were identified from a total of 5280 patients. The incidence of V. post was 0.17%. The location and positional relationship of V. post and UVPI with their neighbouring structures are summarized and compared in Fig. 4.

It is interesting to note that an additional ‘fissure’ divided the upper lobe into ‘two lobes’. Unlike the familiar additional fissure...
in the left upper lobe, which divides the lingual segment from the other segments, this fissure lies longitudinally between S1+2 and S3+4+5, nearly perpendicular to the oblique fissure. This makes the downwards-shift of B^3 more evident in this triad. We named this previously unreported fissure as 'fissure X' (Fig. 5).

**DISCUSSION**

Boyden's triad in the right lung was first proposed in 2021 [4]. Among the variations in the parenchymal division as well as bronchovascular pattern in this triad, the downwards-shift of
B³ is a vital role. Interestingly, similar variations were also identified on the left side. However, there is a significant difference in Boyden’s triad between the left and right sides. On the right side, the B³ is shifted downwards to ‘fuse’ the right upper lobe with the middle lobe, eliminating the horizontal fissure; contrarily, its purpose in the left-sided triad is to ‘divide’ the left upper lobe into ‘two lobes’, with an additional ‘fissure X’. In short, Boyden’s triad on the right side makes the right lung almost a ‘mirror image’ of the left lung, and Boyden’s triad on the left side makes the left lung a ‘mirror image’ of the right lung.

### Table 1: The bronchovascular analyseis of 5 cases with Boyden’s triad (left)

| No. | Bronchus | Artery | Vein |
|-----|----------|--------|------|
|     | B³ downwards-shift type | A³ | A⁴+⁵ | A⁵ on A⁸-10 | V¹+² a+b | V¹+² c | V¹+² d |
| 1   | B³ on B⁴ | A³ on A⁴ | No | Yes | 1 | V. post | 1 |
| 2   | B³ on B⁴ | A³ on A⁴ | No | Yes | 1 | V. post | 1 |
| 3   | B³ on B⁴ | A³ on A⁴ | No | Yes | 1 | V. post | 1 |
| 4   | B³ on B¹+⁵ | A³ on A⁴+⁵ | Yes | No | 1 | V. post | 1 |
| 5   | B³ on B¹+⁵ | A³ on A⁴+⁵ | Yes | No | 1 | V. post | 1 |

A ‘no’ means it does not exist, and a ‘yes’ means it exists. A ‘1’ means the number of the vein.

Figure 3: The variation of vein in Boyden’s triad (left). (A) The normal left upper lobe vein; (B) the V¹+² c drains posterior to the bronchus into inferior pulmonary vein in Boyden’s triad (left).

Figure 4: The location and positional relationship with neighbouring structures of V. post and upper lobe vein posterior to the bronchus intermedius.
side is described as the UVPBI. Asai et al. [6] provided a detailed description and comprehensive summary of this variation in 2005. This anomaly on the left side was not reported until the case reports by Ishikawa et al. [7] in 2012 and Masato in 2017 [8]. However, both publications are case reports; there is no detailed description or accurate incidence data for this variation. Moreover, because there is no bronchus intermedius on the left side, the term UVPBI does not accurately describe the anatomy on the left side; therefore, we described it as a ‘posterior vein’, or V. post. The incidence of V. post was 0.17%, which is much lower than the incidence of UVPBI (5.7%) on the right [6].

It is important to realize that the bronchovascular structures vary greatly at the segmental level, which makes the segmentectomy more challenging than other surgical options. Compared with the identification of variations from high-resolution computed tomography (HRCT), 3D reconstruction helps to make the process more accurate and objective. On the other hand, the 3D-CTBA does not require any additional exams or costs for patients. The well-trained doctors could complete a 3D reconstruction within 30 min by simply a thoracic computed tomography scan. Compared with a lot of time spent on extensive dissections and difficult identification of anatomical variations during surgery, a preoperative half-an-hour ‘investment’ is worthwhile and of great benefits.

CONCLUSION

The $B^3$ downwards-shifting malformation can be found on both lungs, and this is the first description of Boyden’s triad in the left lung; it appears to be much rarer than that in the right lung, with some accompanying unique variations. It is important to note these malformations before a surgery is planned.

Conflict of interest: none declared.

Data availability statement

The data used to support the findings of this study are available from the corresponding author upon request.

Author contributions

Min Zhang: Writing—original draft. Wei-Jie Sun: Data curation. Qing-Chen Wu: Formal analysis. Ming-Jian Ge: Conceptualization.

Reviewer information

Interactive CardioVascular and Thoracic Surgery thanks Paola Ciriaco, Alessia Stanzi and the other anonymous reviewers for their contribution to the peer review process of this article.
REFERENCES

[1] Tsutani Y, Miyata Y, Nakayama H, Okumura S, Adachi S, Yoshimura M et al. Appropriate sublobar resection choice for ground glass opacity-dominant clinical stage IA lung adenocarcinoma: wedge resection or segmentectomy. Chest 2014;145:66–71.

[2] Tsutani Y, Miyata Y, Nakayama H, Okumura S, Adachi S, Yoshimura M et al. Sublobar resection for lung adenocarcinoma meeting node-negative criteria on preoperative imaging. Ann Thorac Surg 2014;97:1701–7.

[3] Boyden EA, Hamre CJ. An analysis of variations in the bronchovascular patterns of the middle lobe in fifty dissected and twenty injected lungs. J Thorac Surg 1951;21:172–80.

[4] Zhang M, Mao N, Wu Q, Tie H, Ge M. Boyden’s triad: the past, present and future. Interact CardioVasc Thorac Surg 2021. https://doi.org/10.1093/icvts/ivab325.

[5] Zhang M, Mao N, Zhang K, Zhang M, Liu Y, Wang RF et al. Analysis of the variation pattern in left upper division veins and establishment of simplified vein models for anatomical segmentectomy. Ann Transl Med 2020;8:1515.

[6] Asai K, Urabe N, Yajima K, Suzuki K, Kazui T. Right upper lobe venous drainage posterior to the bronchus intermedius: preoperative identification by computed tomography. Ann Thorac Surg 2005;79:1866–71.

[7] Ishikawa Y, Iwano S, Usami N, Yokoi K. An anomalous segmental vein of the left upper lobe of the lung: preoperative identification by three-dimensional computed tomography pulmonary angiography. Interact CardioVasc Thorac Surg 2012;15:512–3.

[8] Aragaki M, Iimura Y, Yoshihara Y, Hasegawa N. Anomalous V2 of the left pulmonary vein detected using three-dimensional computed tomography in a patient with lung cancer: a case report. Int J Surg Case Rep 2017;37:208–10.