[11] 马力忠, 莫庆仪, 梁桂明, 等. 支气管肺泡灌洗术在小儿重症肺炎支原体肺炎患者抢救中的临床应用价值 [J]. 中国现代医生, 2015, 53(5): 44-46, 49
Ma Li-zhong, Mo Qing-yi, Liang Gui-ming, et al. Clinical application value of bronchoalveolar lavage in rescue of children with severe mycoplasma pneumonia [J]. China Modern Doctor, 2015, 53 (5): 44-46, 49

[12] 徐学敏. 纤维支气管镜技术在诊治难治性肺炎中的临床价值[J]. 临床和实验医学杂志, 2013, 12(11): 881-882, 884
Xu Xue-min. Study on clinical significance of bronchofiberscopy in diagnosis and treatment of refractory pneumonia [J]. Journal of Clinical and Experimental Medicine, 2013, 12(11): 881-882, 884

[13] 刘玉琳, 耿刚, 唐方芳, 等. 经纤维支气管镜盐酸氨溴索灌洗治疗支原体肺炎并肺不张的疗效及治疗成本分析 [J]. 激光杂志, 2013, 34(3): 92-93
Liu Yu-lin, Geng Gang, Tang Fang-fang, et al. The analysis of effecacy and economic benefit of the treatment with mucosolvan irrigation via bronchoscopy on mycoplasmal pneumonia with pulmonary atelectasis[J]. Laser Journal, 2013, 34(3): 92-93

[14] 梁磊, 杨泽玉, 王亚亭, 等. 纤维支气管镜术对小儿肺炎支原体肺炎合并肺不张的诊治作用 [J]. 医学研究生学报, 2014, 14(4): 401-404
Liang Lei, Yang Ze-yu, Wang Ya-ting, et al. The role of fiberoptic bronchoscopy in diagnosis and treatment of mycoplasma pneumoniae pneumonia associated with atelectasis in children [J]. Journal of Medical Postgraduates, 2014, 14(4): 401-404

[15] 杨璐萍. 发热期重症肺炎患儿纤维支气管镜灌洗治疗效果分析[J]. 医学综述, 2016, 22(13): 2649-2652
Yang Lu-ping. Clinical Efficacy of Bronchoscopy Lavage Treatment for Children with Severe Pneumonia in Fever Stage [J]. Medical Recapitulate, 2016, 22(13): 2649-2652

[16] 丛珊, 白东, 张艳芹, 等. 纤维支气管镜肺泡灌洗治疗小儿难治性肺炎的效果评价[J]. 医学研究杂志, 2015, 44(9): 131-134
Cong Shan, Bai Dong, Zhang Yan-qin, et al. Evaluation of Bronchoalveolar Lavage by Bronchofibroscope in the Treatment of Pediatric Patients with Refractory Pneumonia[J]. Journal of Medical Research, 2015, 44(9): 131-134

[17] 金平珍, 陈志敏. 纤维支气管镜和支气管肺泡灌洗对难治性肺炎的临床疗效和安全性[J]. 中国医药导报, 2013, 10(18): 50-51, 54
Jin Ping-zhen, Chen Zhi-min. Clinical efficacy and safety analysis on fiberoptic bronchoscopy and bronchial lavage in the treatment of refractory pneumonia[J]. China Medical Herald, 2013, 10(18): 50-51, 54

[18] 蔡冬春. 纤维支气管镜在诊治儿童难治性肺炎肺不张中的作用和安全性分析[J]. 临床军医杂志, 2015, 43(3): 279-281
Cai Dong-chun. Role of fiberoptic bronchoscopy in diagnosis and treatment of children's pneumonia with refractory atelectasis [J]. Clinical Journal of Medical Officers, 2015, 43(3): 279-281

[19] 罗泳仪, 候宪云, 黄贤文, 等. 支气管肺泡灌洗术在吸入性肺炎中的应用及安全性分析[J]. 临床肺科杂志, 2014, 19(2): 255-256, 271
Luo Yong-yi, Hou Xian-yun, Huang Xian-wen, et al. Clinical application and safety of broncho-alveolar lavage in the treatment of aspirated pneumonia [J]. Journal of Clinical Pulmonary Medicine, 2014, 19(2): 255-256, 271

[20] 胡丽华, 朱雪娟, 张跃明, 等. 支气管肺泡灌洗在机械通气患者治疗中应用及安全性[J]. 武警医学, 2016, 27(1): 58-60, 64
Hu Li-hua, Zhu Xue-juan, Zhang Yue-ming, et al. Application and safety Study of Broncho-alveolar Lavage on Severe pulmonany infection patient with Mechanical Ventilation Therapy [J]. Medical Journal of the Chinese People's Armed Police Forces, 2016, 27(1): 58-60, 64

(上接第 1370 页)

[14] 董庆, 曹守强, 赵桂彬, 等. 3D 打印技术在非小细胞肺癌诊疗中的应用[J]. 中国数字医学, 2016, 11(1): 87-90
Dong Qing, Cao Shou-qiang, Zhao Gui-bin, et al. Application of three dimensional printing on diagnosis and treatment of non small cell lung cancer[J]. China Digital Medicine, 2016, 11(1): 87-90

[15] Cheng GZ, San Jose Estepar R, Folch E, et al. Three-dimensional Printing and 3D Slicer: Powerful Tools in Understanding and Treating Structural Lung Disease[J]. Chest, 2016, 149(5): 1136-1142

[16] Jones DB, Sung R, Weinberg C, et al. Three-Dimensional Modeling May Improve Surgical Education and Clinical Practice [J]. Surg Innov, 2016, 23(2): 189-195

[17] Vaccarezza M, Papa V. 3D printing: a valuable resource in human anatomy education[J]. Anat Sci Int, 2015, 90(1): 64-65

[18] Zheng YX, Yu DF, Zhao JG, et al. 3D Printout Models vs. 3D-Rendered Images: Which Is Better for Preoperative Planning?[J]. J Surg Educ, 2016, 73(3): 518-523

[19] Kurenov SN, Ionita C, Sammons D, et al. Three-dimensional printing to facilitate anatomic study, device development, simulation, and planning in thoracic surgery [J]. J Thorac Cardiovasc Surg, 2015, 149 (4): 973-979.e1

[20] McMenamin PG, Quayle MR, McHenry CR, et al. The production of anatomical teaching resources using three-dimensional (3D) printing technology[J]. Anat Sci Educ, 2014, 7(6): 479-486

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·生物医学教学·

3D 打印肺段模型在胸外科解剖教学中的应用 *

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摘要 目的：探讨 3D 打印肺段模型在胸外科解剖教学中的应用效果。**方法：**60 名医学新生随机分为 3D 打印组和三维重建图像组，每组 30 人。经相关知识介绍后，参加问卷调查并记录得分，包括理论知识、肺段鉴别、病灶鉴别，共 14 分。**结果：**3D 打印肺段模型能清晰准确地显示出肺脏结构。3D 打印组问卷调查得分显著高于三维重建图像组，差异具有统计学意义(P=0.031)。**结论：**3D 打印肺段模型在医学生肺段解剖教学中的效果优于三维重建图像。

关键词：3D 打印；电视胸腔镜手术；非小细胞肺癌；解剖；教育

中图分类号：R605；R655 **文献标识码：**A **文章编号：**1673-6273(2017)07-1368-03

Application of 3D Printing Lung Segment Model in the Teaching of Anatomy in the Department of Thoracic Surgery*

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ABSTRACT Objective: To explore the application of 3D printing lung segment model in the teaching of anatomy in the department of thoracic surgery. **Methods:** Sixty Medical Freshmen were randomly divided into 3D group and three dimensional reconstruction group, with 30 students in each group. They will participate in the questionnaire survey and record scores with a total of 14 points, including theoretical knowledge, lung segment identification, lesion identification after the introduction of relevant knowledge. **Results:** The structure of the lung can be showed clearly and accurately with the 3D print lung segment model. There were statistically significant differences between the two groups (P=0.031). The scores of questionnaire survey in 3D print group were significantly higher than those in the three dimensional reconstruction image group. **Conclusion:** The effect of 3D printing lung segment model in the teaching of anatomy in medical students is better than that of 3D reconstruction, and it is worth popularizing.

Key words: 3D printing; Video-assisted Thoracoscopic Surgery; Non-Small Cell Lung Cancer; Anatomy; Education

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前言

早在 1939 年有学者首次报道了肺段切除术治疗支气管扩张[1]，在这之后的几十年间，肺段切除术开始治疗肺癌和肺良性疾病。随着近年来微创技术的不断发展，电视胸腔镜肺段切除术已经成为治疗早期肺癌和肺良性疾病的一个重要方法[2]，也是每个胸外科医师都应该掌握的基本技术。但是肺血管、气管的空间结构复杂，变异性大，为肺脏手术带来了巨大的风险，特别是肺段切除术，所以术前肺段解剖的了解十分重要[3]。为了学习肺段解剖，目前很多教具，例如传统的解剖图谱等，都已普遍应用于肺段解剖教学中。这其中也包括肺段的三维重建图像(three-dimensional reconstruction image，3DI)。通过图像效果渲染，3DI 能十分详尽生动地显示肺段内的解剖结构，包括肺血管、气管以及周围的毗邻关系。不少学者开始把这一技术应用于医学实践当中[4]。但是 3DI 也有其自身的缺点，比如它是虚拟的数字影像，不存在物理实体结构，不能提供良好地主观感受和实体模型触觉。目前 3DI 尚不能完全真实地显示肺段的解剖结构，当然也不能代替传统的物理教具。为了解决这个问题，可行的方法是制作一种可以克服 3DI 上述缺陷又能真实显示肺段空间结构的物理模型。那么，3D 打印(three-dimensional printing，3DP)就是能满足这种要求的技术。其优势在于能快速复制出个体化器官模型。在近年来 3DP 已开始应用于胸外科

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领域[5-10]。目前比较 3DP 和 3DI 在医学生和年轻外科医师解剖教学中效果的研究尚不多见[11]。本研究旨在探讨 3D 打印肺段模型在胸外科解剖教学中的应用。

1 资料与方法

1.1 一般资料

经医院伦理委员会批准,参与本研究的学生是哈尔滨医科大学临床医学专业临床实习 1 年级阶段的医学生。所有学生之前未接受过胸外科手术解剖的专业培训。测试方法:60 名医学生接受短暂的肺段解剖及电视胸腔镜肺段切除术的介绍后,随机分为 2 组(3DI 组和 3DP 组),每组 30 人。每组 2 例相应数据模型。接受问卷调查,时间为 30 分钟。调查问卷包括理论知识、肺段鉴别、病灶鉴别,共 14 分,每题 1 分(YES=1 分,NO=0 分),详见表 1。

1.2 3DI 和 3DP 的实现

3DI 和 3DP 的实现:胸外科临床规范化诊疗平台数据库中随机选取接受电视胸腔镜肺段切除术,病理确定为肺腺癌的术前胸部增强 CT 检查患者的影像数据 1 例。患者基本资料:男,76 岁,CT 可见右肺下叶后基底段肿物(S10),病灶直径约 2.24 cm。打印范围为右肺下叶解剖结构及病灶。数据共 400 张断层影像数据。图像重建和 3D 打印方法如本单位之前发表文章所述[12-14]。完成后的 3DI 和 3DP 见图 1。

表 1 调查问卷

Table 1 Questionnaire

ISSUES	YES	NO
1. Can you determine the left or right side of the lung?		
2. Can you determine the lesion of the lung?		
3. Can you measure the size of the lesion?		
4. Can you determine where blood vessel of lung lesion?		
5. Can you judge the bronchial lesions located?		
6. Can you determine the lesion located in which lung segment?		
7. Can you determine the lesions located in the lung segment of the bronchus?		
8. Can you determine the location of the lung segment of the blood vessels?		
9. Can you judge the blood vessels around the lesions?		
10. Can you judge the bronchus around the lesions?		
11. Can you distinguish lung segments of the disease lung?		
12. Do you think the lesion can be resected with lung segment resection?		
13. Is there any risk of blocking the blood vessels around the lesions during surgery?		
14. Is it possible to use the technique to identify the lung segments that can't be identified?		

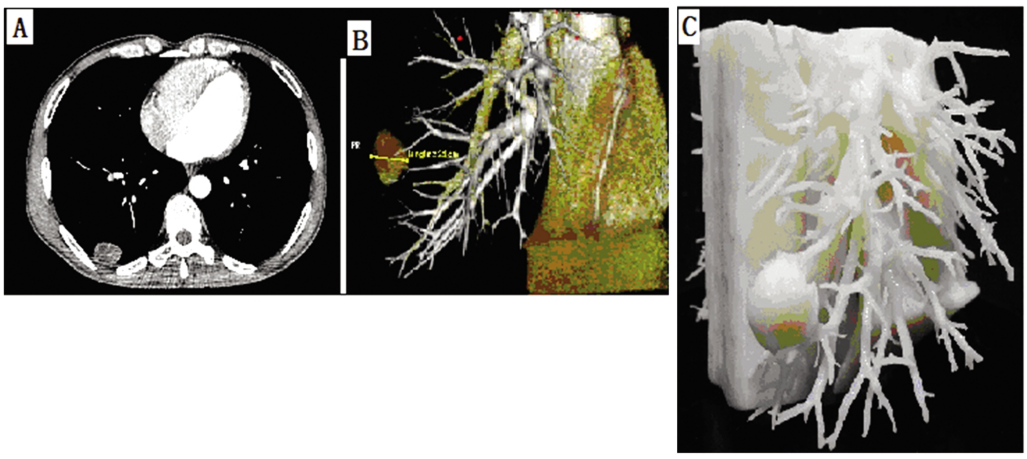

图 1 A: CT 图像; B: 3DI 模型; C: 3DP 模型

Fig.1 A:CT image; B :3DI model; C: 3DP model

1.3 统计学分析

应用软件 SPSS 16.0 (IBM Corporation, Armonk, NY)进行分析。计量资料以平均值± 标准差表示,采用 t test,计数资料采用x^2 test,以 $P<0.05$ 认为差异有统计学意义。

2 结果

3DP 肺段模型能清晰准确地显示出病灶、肺段内和肺段间的血管、支气管结构,并与实际解剖结构一致,这在手术中已得以证实。3DP 模型最小分支直径为 1 mm。两组医学生在性别、年龄、解剖学考试成绩间无明显差异。3DI 得分: 11.43± 1.28,3DP 得分:12.13± 1.17。t test 显示 2 组间存在统计学差异(F=4.909,P=0.031),在教学效果方面 3DP 要好于 3DI。见表 2。

表 2 统计结果

Table 2 The results

Groups	Gender(male/female)	Age	Test scores	Questionnaire scores
3DI	13/17	21.90± 1.35	76.87± 9.06	11.43± 1.28
3DP	14/16	21.53± 0.94	77.80± 7.46	12.13± 1.17
P	0.795	0.226	0.665	0.031

3 讨论

学习肺段空间解剖结构对于医学新生和年轻的胸外科医师而言是很困难的。目前,肺脏医学影像主要来自于 CT、MRI 等影像学检查,这些图像大多数是二维的,也就是 2D 的。肺外科医师需要长时间的临床经验才能够在人脑中形成 3D 视觉印象,只有这样才能掌握复杂多变的肺脏解剖[13,14]。这种在人脑内形成的三维立体印象是模糊的,其稳定性较差,受主观感受影响较大,而且需要长时间的临床经验积累,极为不利于年轻肺外科医师的成长[15]。为了解决这个问题,传统的方法是通过解剖尸体或者解剖图谱来理解这个问题。尸体解剖效果较好,但是由于道德、伦理方面的种种问题,尸体来源得不到保证,大多数医学院校都面临着尸体资源严重短缺的困难[16]。3DP 可以很好的解决这个问题,其优点在于精度高,可重复易保存,价格相对便宜,学生心理容易接受,可单独显示内脏的脉管系统,同时 3DP 模型也比塑料灌注模型的效果好[17]。

应用 3DP 培养教育医学生和年轻医师的最终目的是掌握复杂的肺外科手术技术。本研究中,3DP 肺段模型能清晰准确地显示出病灶、肺段内和肺段间的血管、支气管结构,并与实际解剖结构一致,这在手术中已得以证实。3DP 模型最小分支直径为 1 mm, 也足以满足手术的需求。另外, 在教学效果方面 3DP 也要好于 3DI,这与国外学者的报道类似[18],未来还需更多的前瞻性研究评价它缩短新生学习曲线的实际效果。

3DP 能直观的显示出肺内复杂的血管、气管系统的分布、走行、变异及其与病灶的毗邻关系,并能制定手术计划,模拟肺外科手术[19]。未来,3DP 数据库的建立可以在术前精确掌握肺脏复杂解剖结构来指导手术和预判断术中存在风险,在术后进行复杂手术的复盘,以便更好的总结临床诊疗经验。以 3DP 数据库资料为基础,比较不同手术方案的优劣,智能化制订合理的个体化手术方案,为患者提供个体化治疗,这也是 3DP 教学的一个方向。

制作高质量的 3DP 建模过程中需要临床医生、影像医生和计算机工程师的密切配合。其中,以外科医生作为主导,联合其他相关学科专家学者组成研发团队,设计出适合于肺外科诊疗的 3DP 平台, 并充分利用这一技术进行临床教学和虚拟手术研究[13,14]。3DP 的应用目前还有诸如价格高昂、打印时间长等诸多因素限制,相信随着这一技术的普及这些困难都将一一被解决[20]。未来需要更多的医生关注 3DP 在临床医学中的应用。

综上所述,本研究中 3DP 能改善肺段解剖教学效果,医学生可以利用 3DP 肺段模型学习复杂的肺段解剖结构,值得推广。

参 考 文 献(References)

[1] Churchill ED, Belsey R. Segmental pneumonectomy in bronchiectasis: the lingula segment of the left upper LOB[J]. Ann Surg, 1939, 109(4): 481-499

[2] Ghaly G, Kamel M, Nasar A, et al. Video-assisted thoracoscopic surgery is a safe and effective alternative to thoracotomy for anatomical segmentectomy in patients with clinical stage I non-small cell lung cancer[J]. Ann Thorac Surg, 2016, 101(2): 465-472

[3] Tane S, Ohno Y, Hokka D, et al. The efficacy of 320-detector row computed tomography for the assessment of preoperative pulmonary vasculature of candidates for pulmonary segmentectomy [J]. Interact Cardiovasc Thorac Surg, 2013, 17(6): 974-980

[4] Ikeda N, Yoshimura A, Hagiwara M, et al. Three dimensional computed tomography lung modeling is useful in simulation and navigation of lung cancer surgery[J]. Ann Thorac Cardiovasc Surg, 2013, 19(1): 1-5

[5] Akiba T, Nakada T, Inagaki T. Simulation of the fissureless technique for thoracoscopic segmentectomy using rapid prototyping [J]. Ann Thorac Cardiovasc Surg, 2015, 21(1): 84-86

[6] Han B, Liu Y, Zhang X, et al. Three-dimensional printing as an aid to airway evaluation after tracheotomy in a patient with laryngeal carcinoma[J]. BMC Anesthesiol, 2016, 16(1): 6

[7] Cheng GZ, Folch E, Brik R, et al. Three-dimensional modeled T-tube design and insertion in a patient with tracheal dehiscence [J]. Chest, 2015, 148(4): e106-108

[8] Park JH, Hong JM, Ju YM, et al. A novel tissue-engineered trachea with a mechanical behavior similar to native trachea[J]. Biomaterials, 2015, 62: 106-115

[9] Morrison RJ, Hollister SJ, Niedner MF, et al. Mitigation of tracheobronchomalacia with 3D-printed personalized medical devices in pediatric patients[J]. Sci Transl Med, 2015, 7(285): 285ra64

[10] Morrison RJ, Kashlan KN, Flanangan CL, et al. Regulatory Considerations in the Design and Manufacturing of Implantable 3D-Printed Medical Devices[J]. Clin Transl Sci, 2015, 8(5): 594-600

[11] Kong X, Nie L, Zhang H, et al. Do Three-dimensional Visualization and Three-dimensional Printing Improve Hepatic Segment Anatomy Teaching? A Randomized Controlled Study[J]. J Surg Educ, 2016, 73 (2): 264-269

[12] 董庆, 崔键, 辛衍忠, 等. 数字医学技术在非小细胞肺癌诊疗中的应用价值[J]. 中国数字医学, 2013, 8(7): 87-89+92
Dong Qing, Cui Jian, Xin Yan-zhong, et al. The study of the applicated value of digital medical technology on diagnosis and treatment of non-small cell lung cancer [J]. China Digital Medicine, 2013, 8(7): 87-89+92

[13] 董庆, 曹守强, 申宝忠, 等. 基于医疗数据信息集成系统的 3D 打印技术在肺癌手术中的应用 [J]. 现代生物医学进展, 2016, 16(3): 457-460
Dong Qing, Cao Shou-qiang, Shen Bao-zhong, et al. Application of 3D printing technology based on medical data information integration system in lung cancer surgery [J]. Progress in Modern Biomedicine, 2016, 16(3): 457-460

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