Open source software e-learning system for CT images in young thoracic surgeons

Kazuhiro Ito[1, 2], Junichi Shimada[2], Daishiro Kato[2], Motohiro Nishimura[2, 3], and Satoru Okada[2]

[1] Department of Thoracic Surgery, Kyoto Yamashiro Medical Center, 1-27 Kizuekimae, Kizugawa 619-0214, Japan
[2] Division of Chest Surgery, Department of Surgery, Kyoto Prefectural University of Medicine, 465 Kajiicho, Kamigyo, Kyoto 602-8566, Japan
[3] Department of Thoracic Surgery, Suita Saiseikai Hospital, 1-2 Kawazonocho, Suita, Osaka 564-0013, Japan

Correspondence:
Kazuhiro Ito, MD, PhD.
Department of Thoracic Surgery, Kyoto Yamashiro Medical Center, 1-27 Kizuekimae, Kizugawa, Kyoto 619-0214, Japan.
E-mail: kazuitoh@me.com
Telephone: +81-774-72-0235
Fax: +81-774-72-2155

Abstract

Background Open source software e-learning system for improving young thoracic surgeons' interpretations of chest computed tomography (CT) images was evaluated.

Methods An e-learning system was established for medical image interpretation using open source software that can be accessed from multiple sites. Virtual network computing (VNC), a graphical desktop sharing protocol, was used to control the remote server desktop screen. OsiriX, an image-processing package, was installed on the server to share medical images. Chest CTs were extracted from remote hospitals, anonymized, and uploaded to the secure server. The participants accessed the server via high-speed Internet secured with a virtual private network. Five young thoracic surgeons (3-8 years of experience) were instructed to interpret a preoperative chest CT from a remote partner hospital. The young surgeons then created a 3-dimensional configuration of the pulmonary vessels before procedure using the 2-dimensional scans. Next, 5 expert thoracic surgeons ranked the renderings on a 10-point scale. The edited surgical video with the actual pulmonary configuration was uploaded to the web server, and the young thoracic surgeons watched the video as a self-education module. They also commented on their peers' preoperative images of the pulmonary vessels.

Results The scores of the 5 interpretations and drawings of pulmonary vessel branching patterns of patients with lung cancer undergoing lobectomy increased with years of experience.

Conclusions The young thoracic surgeons virtually learned lobectomy using an e-learning system. This virtual resource will help young thoracic surgeons accumulate greater experience.

Keywords

Virtual network computing, open source software, e-learning, medical image, thoracic surgeon

Introduction

In thoracic surgery, preoperative interpretation of chest computed tomography (CT) is essential for detecting the branching patterns of pulmonary vessels. The exact imaging of pulmonary vessels allows proper management of the surgical procedure. Thoracic surgeons repeatedly confirm the branching patterns of pulmonary vessels, especially pulmonary arteries, pre- and periprocedurally. Surgical errors in managing unexpected branches of pulmonary vessels could result in patient mortality. Thus, while young thoracic surgeons should experience as many surgical cases as possible to become competent, experienced thoracic surgeons, the number of operations in which they can participate is limited to the procedures performed in the hospital where they are employed.

Video-assisted thoracic surgery (VATS) lobectomy is a standard treatment for lung cancer [1] and is associated with minimal invasiveness and outcomes equivalent to those of open lobectomy in stage I non-small cell lung cancer [2]. Since VATS lobectomies are usually recorded, young thoracic surgeons can watch these videos repeatedly, but the number of unique VATS lobectomies is typically also limited within the range of surgeries performed in the hospital.

Recent developments in information and communication technology (ICT) fields have enabled rapid computer screen sharing, resulting in the successful application of virtual network computing (VNC) for interactive remote conferences involving medical images [3-5]. VNC is a graphical desktop-sharing system for remotely controlling another computer [6] that allows keyboard and mouse events to be sent from one computer to another, relaying the graphical screen updates back in the other direction over a specific, secured network. We previously reported the use of VNC for interactive teleconferences among a general thoracic surgery team [3-5].

In this study, we applied VNC to an e-learning system for young thoracic surgeons.

Methods

Network configuration

The network configuration is shown in Fig.1. A VNC server (MacBook, Apple Inc., CA, USA) was located at the Kyoto Prefectural University of Medicine (KPUM). The server was connected to a Gigabit Ethernet (maximum bandwidth 10 Gbit/s) with layer-2 security. The client connected to the server using the Gigabit Ethernet or high-speed Internet via a virtual private network (VPN). All communication between the server and clients was encrypted. High-speed Internet included a commercially available optic fiber, asymmetric digital subscriber line (ADSL), or a long-term evolution (LTE) wireless service.

Open source software

A free, open-source, image-processing software package (OsiriX, Pixmeo, Geneva, Switzerland) was installed on the server to share the DICOM-type medical images [7]. The DICOM images of patients undergoing lobectomy were obtained from Kyoto Yamashiro Medical Center after anonymization to protect the patients' personal data. The patients' DICOM data were sent to the server by file transfer protocol (FTP). The data were imported into the OsiriX software controlling the remote server desktop using VNC, a graphical desktop screen sharing protocol. The Mac operating system (OS 10.6, 10.7, 10.8) included a built-in server and client component for VNC, allowing easy VNC system establishment. An alternative VNC client service was recommended for Windows users [8].

A voice communication system using Mumble software, a free, cross-platform voice communication application, was set up if remote technical support was needed. Another server (Mac mini, Apple Inc., USA) for voice communication using Murmur software was located in KPUM and connected to the same network as the VNC server. This server was also used as a web server for the e-learning as described later.

E-learning system

The e-learning system's outline is shown in Fig. 2. Specialist thoracic surgeon set up one surgical case on the VNC based e-learning system and sent the e-mail to the young thoracic surgeon to make interpretation of the CTs and draw the branching patterns of the pulmonary vessels. Young thoracic surgeons did it and returned the e-mail with the drawing. Specialist thoracic surgeon proceeded the lobectomy, edited the surgical video, and uploaded to the web server. Then, all of the thoracic surgeons accessed the web page and reconfirmed the anatomy of the pulmonary vessels comparing with their preoperative drawing.

Participants

A total of 5 thoracic surgeons with 3-8 years' experience participated in this study, of whom 3 were working in the University hospital and 2 were in different satellite hospitals. In addition to their routine clinical work, they were instructed to interpret remote chest CT scans of the patients undergoing lobectomy. All surgeons, both young and experienced, provided informed consent for this software study.

Chest CT interpretation

The participants were instructed by email to interpret chest CTs before the lobectomy. The client connected to the server using the appropriate security protocol. All participants used the integrated software, which enabled them to complete the login process automatically (that is, they logged in with the secure VPN, activated voice communication, and connected to the VNC server). This integrated software allowed participants to forgo the traditional login process of repeatedly accurately entering their username and password [9]. After successful login, they controlled the server desktop screen from their desktop via keyboard typing and mouse manipulation. Participants interpreted the pulmonary vessels using OsiriX software installed in the server, rendered the figure of the pulmonary vessels with attention to the branching patterns, and replied to the email with preoperative findings and their pictures.

Evaluation and rating

Following drawing submission, 5 expert thoracic surgeons with 17-25 years of experience evaluated each young surgeon's figures of pulmonary vessel branching patterns and ranked them on a 10-point scale. Rankings were based on the accuracy of the number, the location, and the direction of the branching patterns of pulmonary vessels. The achieved scores were returned as mean values.

Operation videos and comments upload

The lobectomy was performed via VATS. The lobectomy videos from the endoscope were recorded using a hard disk recorder. The videos included the entire lobectomy without identifying information. The video data was exported to another hard disk, then imported to the other MacBook for editing. Editing included some scene segmentation to trim the procedure to within 10-15 minutes long for easy viewing while maintaining important pulmonary vessel manipulation.

The short, scene-segmented lobectomy videos, some comments about the surgical technique of vessel management, and evaluation of the figures were uploaded to the web server.

Web system

A web server (Mac mini, OS 10.8.5) using the same server machine as the voice communication program was set up in KPUM. For ease of use, we used the Mac mini's server application's built-in blog service.

Participants accessed the web server via secure VPN after receiving the e-mail announcing completed data upload. They watched the video, viewed the experienced surgeon's comments, and received feedback on their branching patterns of the pulmonary vessels figure. After viewing the web page's contents, participants commented on the video of the lobectomy and reevaluated the preoperative drawings of the pulmonary vessels' branching patterns.

Results

Five lobectomies were uploaded to the e-learning system. Cases 1 and 4 were right upper lobectomies, cases 2 and 3 were left upper lobectomies, and case 5 was a right lower lobectomy.

Four young thoracic surgeons each made interpretations of CT scans of 5 different patients with lung cancer undergoing lobectomy and drew the branching patterns of pulmonary vessels. Since 1 young surgeon joined along the way, he made only 2 interpretations. The 5 participants' scores tended to increase (Fig. 3); that is, more experienced surgeons in the course tended to receive better scores than less experienced surgeons. Surgeons' drawings are shown in Fig. 4.

A sample of the web page is shown in Fig. 5. The specialist thoracic surgeon made the body column with operation videos. The young thoracic surgeons wrote the comments of the surgery and reconfirmed the branching patterns of the pulmonary vessels.

Discussion

This study proposed utilizing an e-learning system with open source software to view and interpret CT chest scans before a lobectomy, paying particular attention to the branching patterns of pulmonary vessels. Young thoracic surgeons were able to virtually experience and participate in lobectomies for patients with lung cancer. This approach was comprehensive and interactive, because it included an abstract describing the patient in his preoperative condition integrated with the chest CTs. It also required the participant to demonstrate understanding and comprehension of the branching patterns of pulmonary vessels with a drawing, provided experienced feedback via the surgical video, and provided peer feedback via participant video comments and discussion with other members.

A similar web service of WeBSurg was currently found in use [10]. An advantage of WeBSurg is its wealth of surgical videos, which include patient abstracts and procedural films. Although our system still has a limited selection of lobectomy cases, it does offer an interactive component made up of preoperative interpretation of chest CT and drawing the branching patterns of pulmonary vessels, which was a substantial advantage. Traditionally, thoracic surgeons have relied on their own understanding of multiple preprocedural 2-dimensional (2D) CT images to construct a mental 3D image of pulmonary vessels. Although advances in ICT have enabled us to easily create these 3D images using open source software like OsiriX, thoracic surgeons still tend to rely more on their mental 3D reconstructions. In fact, experienced thoracic surgeons operate on the patients almost exclusively according their mental images and rarely watch the computer desktop during surgery. This ease of mental reconstruction ensures safer, more effective surgeries. It is, therefore, important to improve the computer competency of 3D reconstruction in conjunction with mental interpretation of preoperative chest CT scans.

It was easy and cost-effective to establish a VNC-based remote interpretation system using open source software, although there were some limitations of use. For example, there was a limit to how many members could log on simultaneously. Multiple clients are allowed to connect to the same Macintosh server, but only 1 client can send the control event to the server. When 2 or more clients send the control event to the server simultaneously, the server desktop does not send the desktop screen back correctly. In such cases, we set up a secondary voice communication method, because VNC did not support audio transmission. When using this secondary audio communication, one client was chosen to control the server, and the others became listeners. An unexpected interactive teleconference took place between a young and an expert thoracic surgeon, when a young thoracic surgeon connected to the server while the expert thoracic surgeon was uploading the web contents. In these circumstances, the number of members might be preemptively limited to 5 or 6 to avoid the inconvenience of VNC-based system.

Another potential limitation was the possibility of disclosing private patient data. To mitigate this possibility, we anonymously exported the chest CT DICOM images. All communications between remote locations were conducted via secure VPN or the least network with layer-2 security. The end client was unable to import the DICOM data, and the system was only accessible to members of KPUM's thoracic surgery team. Therefore, we believe that these and similar security measures adequately protect patient data.

The ultimate goal is to produce a "circle" of e-learning. A new thoracic surgeon will join the e-learning system with minimal experience and a more experienced thoracic surgeon will complete the e-learning course. The new thoracic surgeon will learn and gain experience using the accumulation of past lobectomy cases archived in the e-learning system as more surgeons participate over time. Upon completion of the course, the graduate thoracic surgeon will then participate in this system as a rating member of experienced thoracic surgeons. This cycle will repeat and new thoracic surgeons will benefit from and learn the history of our experience and method of lobectomy. This program will help young, less experienced thoracic surgeons to more accurately construct mental 3D images of pulmonary vessels via increased exposure to a variety of remotely performed cases.

In conclusion, 5 young thoracic surgeons successfully experienced additional, virtual lobectomies using our novel, comprehensive, interactive e-learning system. This system that helps accumulate surgical cases with regular expert feedback and peer communication will help a new thoracic surgeon by offering virtual experience in real-world operations. This resource will enable surgeons to develop their expertise that would aid in the development of their thoracic surgery skills.

Acknowledgements

This study was supported with Grants-in-aid for Scientific Research (C) (No 15K08561) of the Japan Society for the Promotion of Science.

Conflict of interest

The authors declare that they have no conflict of interest.

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Fig. 1 Network configuration. Two server machines were set up at the Kyoto Prefectural University of Medicine; one for VNC, and one for voice communication and web service. The clients connected via high-speed Internet over a secure virtual private network or least Gigabit network with the layer-2 security. VPN: virtual private network

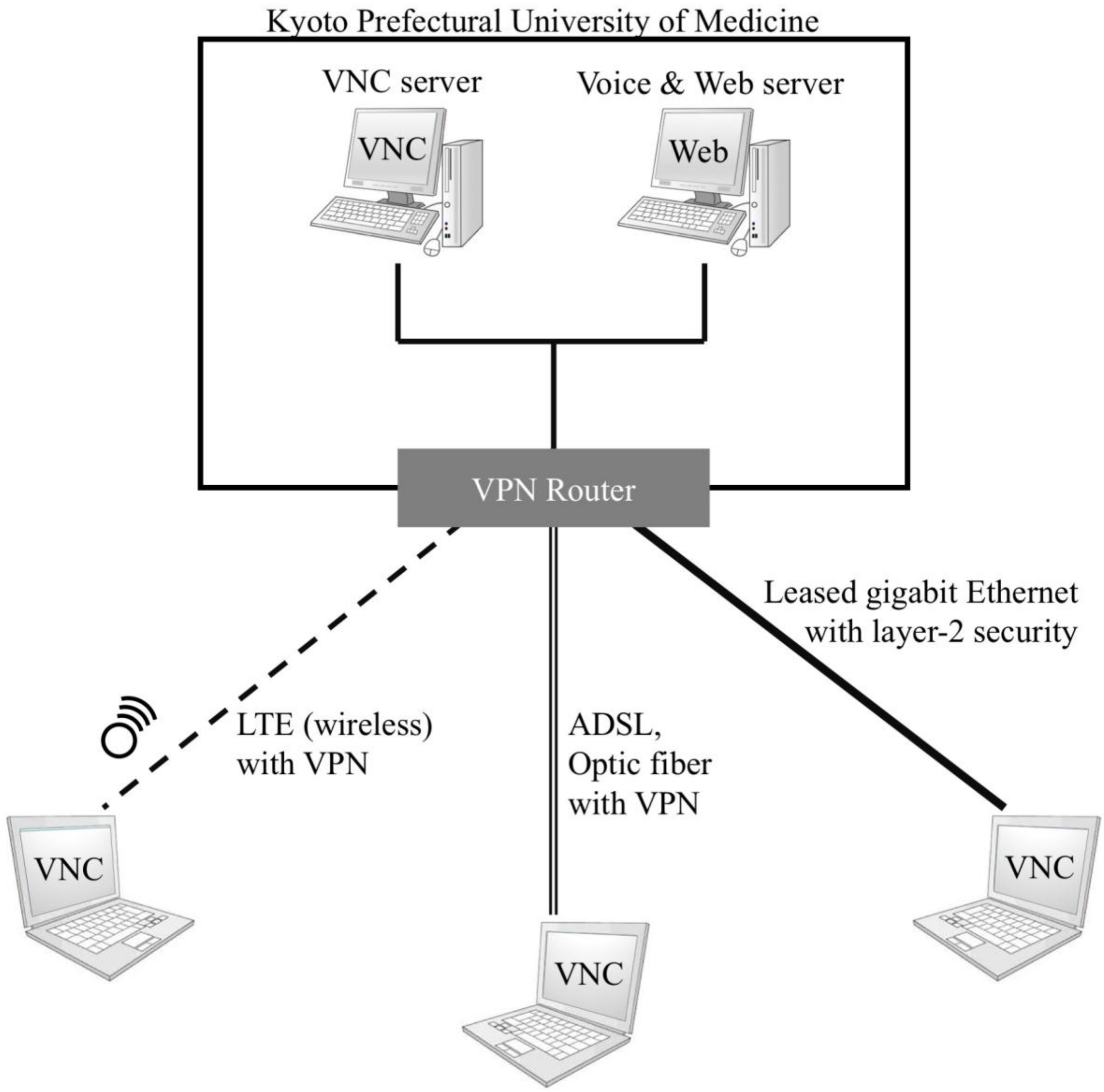

Fig. 2 Outline of the e-learning system

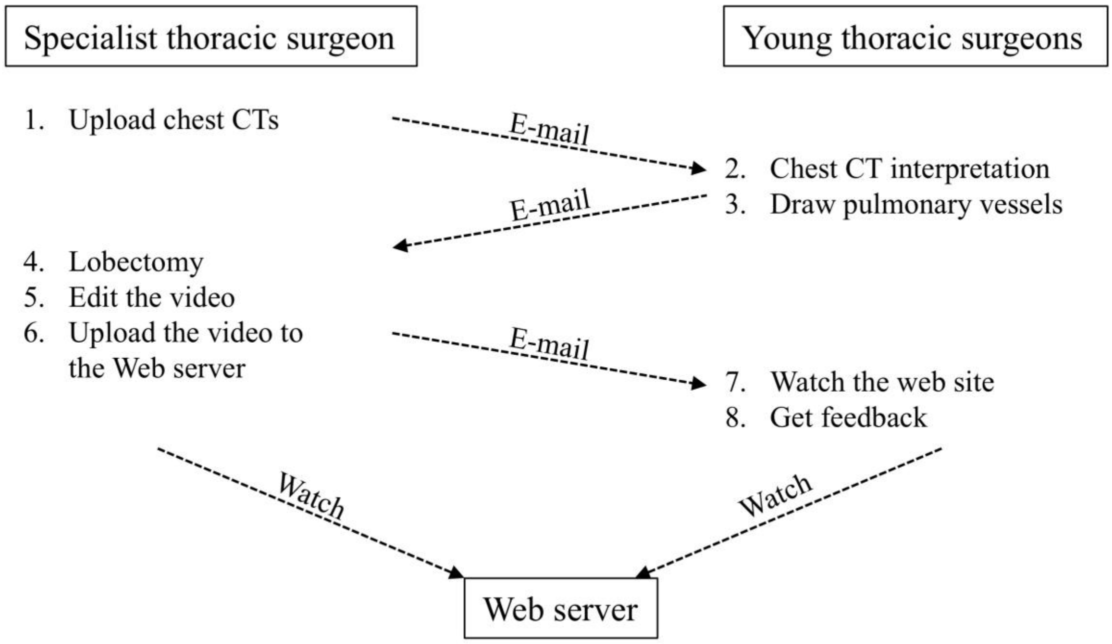

Fig. 3 Young thoracic surgeons' scores

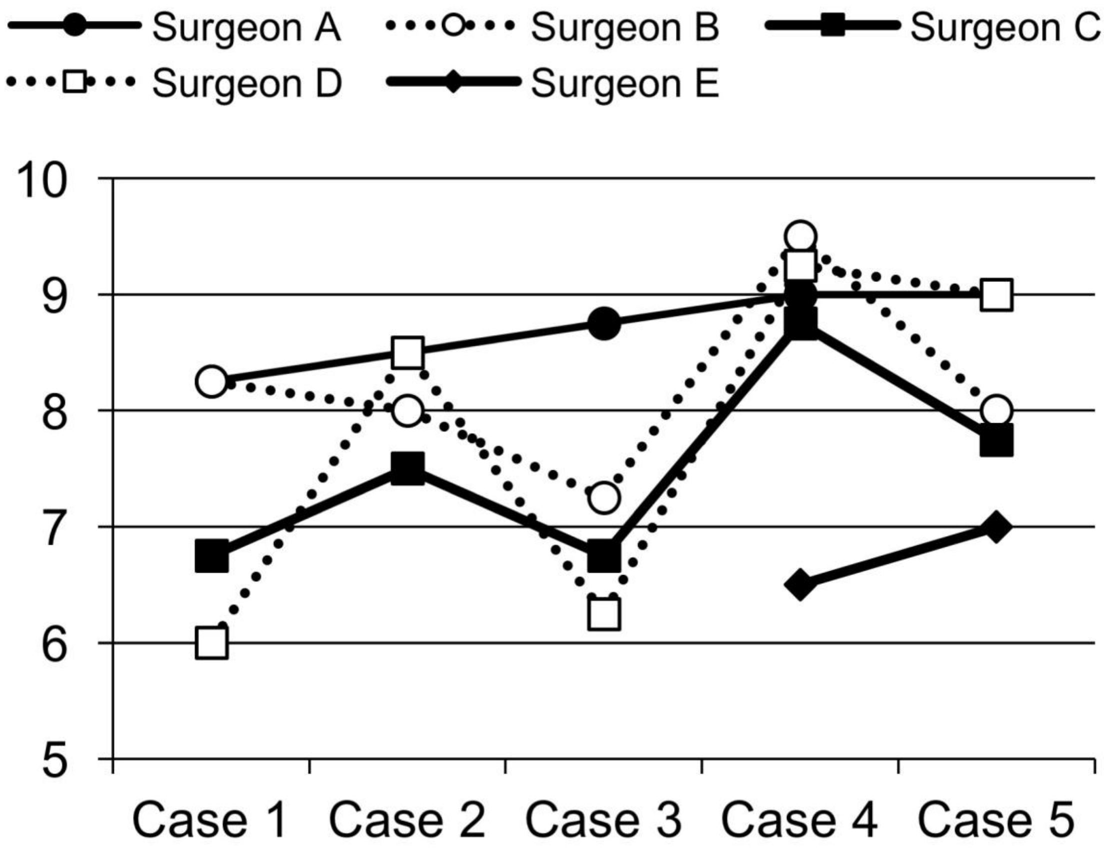

Fig. 4 Young thoracic surgeons' pulmonary artery drawings. Cases 1 and 4 were right upper lobectomies, cases 2 and 3 were left upper lobectomies, and case 5 was a right lower lobectomy. exp: experience

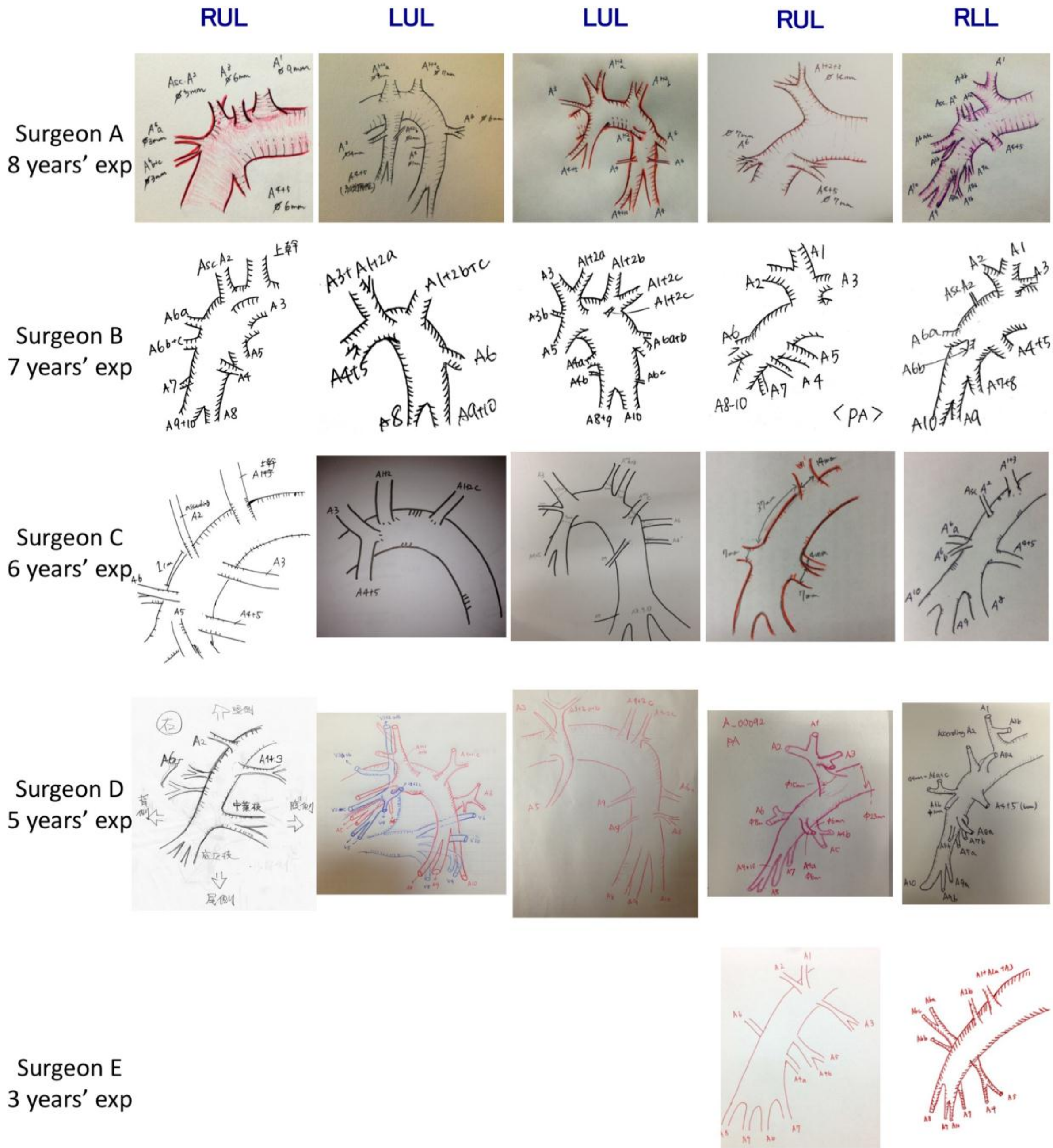

Fig. 5 A sample of the web page