Virtual Thoracic Surgery

by Thomas L. Bauer, MD, and Raymond Green, DO

In the 1950s, Morton Heilig wrote of an "Experience Theater" that could encompass all the senses in an effective manner, drawing the viewer into the onscreen activity. In the early 1960s, he developed a machine that could take the participant on a motorcycle "ride" through Brooklyn, experiencing the sights, sounds—even the smells—of the event. Who knew that 40 years later his idea would be used to save lives?

Virtual reality (VR) is a technology that allows a user to interact with a computer-simulated environment, be it a real or imagined one. Through VR the participant can experience many different scenarios without risk of harm. These scenarios can be used to inform, entertain, or even safely train a participant in a skill or duty that could pose harm in the real world. Over the last 30 years, VR training has been widely used in many different venues including air travel, military training, and even medicine. VR has had a prolific effect on medicine and surgery and is being used in almost all medical fields today. From training to assisting seasoned physicians with diagnosis—VR is there.

In the field of thoracic surgery, VR's many different applications can be broken down into three major categories:

- Evaluating the airway (assessment of bronchial stenosis, foreign body aspiration)
- Planning and assisting in therapeutic intervention (assisting in transbronchial biopsy)
- Assisting in education (simulators and anatomic references).

Here is a look at each of these categories, along with the use of virtual bronchoscopy in thoracic surgery today.

When patients require an evaluation of the airway, frequently it will involve a CT scan of the chest. CT of the chest is a necessary part of the staging and evaluation in patients with lung cancer. CT scanners collect data and display in two dimensions; the axial images that we are familiar with. If the scanner is set to take sub-centimeter slices and these slices are stacked one upon another using computer software, a three-dimensional image can be obtained. The virtual images can be digitally modified to select certain densities and isolate specific structures such as bone or lung tissue, a process called segmentation. These images can then be manipulated in many different ways allowing the area under examination to be viewed from almost any perspective. VR of the chest that allows us to create three-dimensional images of the lung and airways is known as virtual bronchoscopy (VB).

Several different studies have proven VB in conjunction with axial CT to be superior to CT scan alone in the diagnosis and assessment of airway masses and airway stenosis.[1, 2] This accuracy allows for proper selection of endoluminal stents in patients with stenosis. Frequently these patients will undergo a real-time evaluation of the airway using a fiberoptic endoscope, known as flexible bronchoscopy (FB). FB is a mainstay for foreign body aspiration, and also frequently used during the workup of airway mass. FB, unlike VB, is invasive and frequently requires sedation. Occasionally stenoses are so narrow a bronchoscope cannot be passed to evaluate distal anatomy. VB excels over FB in that VB is able to assess the distal part of the stenosis, and has been shown to be accurate down to the eighth generation of bronchi.[3] VB has been shown to be similar to FB in grading stenosis,[4] and may actually be better at determining stenosis length.

VB is also a useful tool in evaluating the pediatric airway. Haliloglu demonstrated 100 percent sensitivity and specificity in diagnosing foreign body aspiration.[5] Kircher found similar results and was able to avoid FB in 73 percent of his pediatric patients.[6] Avoiding FB in children with foreign body aspiration avoids unnecessary tracheal instrumentation which can complicate surgical intervention.

There are down sides to VB.[7] It is very poor at evaluating subtleties in the mucosa. Frequently the subtle mucosal changes in the airway seen in FB are what lead to further workup. VB can have a high false-positive rate for detecting masses if there are increased tracheal secretions such as thick sputum or coagulated blood. Again, the low mucosal sensitivity does not allow VB to differentiate thick mucous from a mass. Therefore, patients that have hemoptysis (coughing up blood) may not be candidates for sole VB evaluation. VB is unable to show dynamic lesions. Because the VB image is, in essence, a reconstituted still image, it is unable to detect lesions that are present with movement, such as vocal cord lesions. Finally, VB is a non-invasive study. Because of this, VB is unable to take biopsy samples. This is the major reason that VB will most likely never replace FB in the diagnosis and staging of airway lesions.

In examining the use of VR for planning and assisting intervention, it has already been show that VB allows for a more accurate assessment of stenosis. This assessment allows for better pre-operative planning in stent size and placement. The use of VB to evaluate the anatomy of specific patients will also allow for better operative intervention. Knowledge of anatomical landmarks or variants will make the surgical approach more accurate and can decrease the risk of intraoperative mishaps.

Patients with lung masses frequently will undergo transbronchial biopsy for diagnosis of masses or staging of cancer. It has been well demonstrated that transbronchial biopsy in patients that have intraluminal changes with their mass (erosion through mucosa, intraluminal compression) have a 94 percent success rate for obtaining diagnostic tissue. However, eliminating the visible changes in the mucosa causes the success rate to drop below 60 percent.[3] Shinagawa showed that by using CT-guided transbronchial biopsy following VB successful diagnostic biopsies were obtained almost 70 percent of the time versus less than 35 percent without the VB and CT guidance. Later, Hopper demonstrated using VR; endoscopists were able to increase their success rate for transbronchial biopsy without mucosal changes from 55 percent to 83 percent by employing a VB model.[8]

Virtual Education

The use of VR in education is very broad. Anatomy programs that allow for "fly-by" three-dimensional images are useful to medical students and physicians alike. Residents are able to practice many different skills safely through the use of simulators. Some simulators are machines with only computer screens and instruments to create a VR environment while others use complex anatomical mannequins that can simulate disease processes and even respond to interventions. Two studies comparing novice and experienced endoscopists have demonstrated that the use of simulation can improve dexterity, speed and accuracy in the novices equal or surpassing those of the experienced.[9,10] VR simulation has demonstrated itself as a useful tool and is being placed in the curriculum of some general surgery residencies.

In summary, VR is a technology that not only has proven benefit in certain clinical applications, but one that continues to grow and diversify. It has been proven helpful for evaluating airway masses and assisting physicians for planning interventions such as stent placement and operative interventions. It has proven benefit in pediatric populations, and has been shown to increase the yield of transbronchial biopsy. It seems the progressive imagination that gave us the "Experience Theater" of the 1950s will be the same imagination that finds new and innovative uses for VR in the future.

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