Image Gallery: A Tool for Rapid Endobronchial Lesion Detection and Display Using Virtual Bronchoscopy

Ronald M. Summers

THREE-DIMENSIONAL reconstruction of large datasets are increasingly being used in diagnostic radiology. However in this age of decreasing reimbursements and increasing workload, it is becoming more and more difficult to interpret these studies in a timely and efficient manner. Thus, new methods of data display and analysis are required to make interpretation of these data feasible. For example, virtual bronchoscopy can be used to produce detailed three-dimensional reconstructions of the airway, but it can be time consuming to navigate the virtual bronchoscopy to locate potential lesion sites. One solution to this problem is to use computer algorithms which locate potential lesions automatically. Potential lesion sites determined by the computer can then be presented to the physician who can accept or reject them on clinical grounds. But what does the radiologist do if the computer detects a large number of candidate lesion sites? To solve this problem, we have taken a computer graphics tool developed for the computer-aided design community (the "Design Gallery") and adapted it by developing a new tool (the "Image Gallery") to meet the needs of the radiologist confronted with this new clinical problem.¹

METHODS

Eighteen virtual bronchoscopy reconstructions of the central airways were produced from helical CT scans of the thorax of sixteen patients. Seven patients had known endobronchial disease and the remaining nine patients served as controls.² Feature analysis was employed to identify potential endobronchial lesion sites.³⁻⁵ The lesion sites so identified were colored to indicate their location during virtual bronchoscopy.

The Image Gallery software was developed in C++ and OpenInventor using the RapidApp graphical application development tool (Silicon Graphics, Mountain View, CA).⁶ The software was developed and evaluated on a Silicon Graphics Indigo2 workstation with Maximum Impact graphics and 195 MHz MIPS R10000 CPU.

The Image Gallery consists of a central window surrounded by an array of 12 smaller windows (Fig 1). Both the large and small windows display the surface-rendered virtual bronchoscopy model. The central window displays an exoscopic (exterior) view of the airway. Each small window shows a close-up of a potential lesion site. In this way, up to 12 potential lesion sites at a time may be viewed simultaneously. If there are more than 12 potential lesions, additional groups of potential lesions can be displayed by clicking on a button. The location of the potential

lesion site in each smaller window is indicated in the large central window using numbered arrows. The number associated with each arrow in the large window identifies the corresponding small window. Each window (both large and small) are independent "scene viewers" (using the terminology of OpenInventor), each capable of allowing manipulation of the three-dimensional orientation of the airway using simple combinations of mouse motion and button presses. Thus the radiologist can fine tune the viewing angle and distance to each lesion as desired.

Menu options and push buttons in the graphical user interface of the Image Gallery provide additional capabilities. For example, potential lesion sites which are implausible due to artifact can be discarded by clicking on the "lesion" in its small window and using the Discard Lesion command. The remaining lesion sites can be saved as a new OpenInventor model. Transparency of the model can be changed using a thumbwheel to better view the lesion indicators in the central window. The lesion coloring can be turned off if desired. A formal report of a virtual bronchoscopy study can be produced, consisting of a screen capture showing the position and appearance of all nondiscarded lesions. Data describing the kept and discarded lesions, such as size or curvature, can be printed out for further analysis.

We investigated the time saving aspects of the Image Gallery by measuring the time required to evaluate the airway for endobronchial lesions. For each virtual bronchoscopy fly-through, we recorded three times: the time required to navigate the entire reconstructed airway looking for lesions, the time to look at each lesion individually using a virtual bronchoscopy navigation tool,⁷ and the time to inspect the potential lesions using the Image Gallery. In each case, the virtual bronchoscopy was processed with our automatic lesion detection algorithm prior to inspection.⁵ A paired two-tailed t-test was used to determine statistical significance.

RESULTS

True lesions were accurately identified using all three methods of visual inspection. There were 175 potential lesions and 30 true lesions on the 18 virtual bronchoscopy studies. Inspection times recorded using the Image Gallery (mean $\pm$ standard

From the Diagnostic Radiology Department, Warren Grant Magnuson Clinical Center, National Institutes of Health, Bethesda, MD.

Address reprint requests to Ronald M. Summers, M.D., Ph.D., Diagnostic Radiology Department, National Institutes of Health, Bldg. 10, Room 1C660, 10 Center Dr Msc 1182, Bethesda, MD 20892-1182.

This is a US government work. There are no restrictions on its use.

0897-1889/98/1103-1016\$0.00/0

Fig 1. Image Gallery showing endobronchial lesions in a 35-year old woman with known lymphomatous airway nodules. The large central window shows an exoscopic view of the airway. The smaller windows surrounding the central window show close-ups of potential lesion sites. Numbered arrows pointing at potential lesions on the exoscopic view refer to the corresponding numbered endoscopic view in a small window.

error of mean: 46 ± 5 sec) were 77% faster than those obtained by navigation of the entire airway (198 ± 15 sec) ($P = 8 \times 10^{-9}$) and 51% faster than those obtained by inspection of each potential lesion site individually (95 ± 14 sec) ($P = 0.003$).

DISCUSSION

We have shown that use of the Image Gallery software reduces the amount of time required to inspect the central airways for endobronchial lesions by 51% to 77%. This time savings is not unexpected since the Image Gallery presents up to twelve potential lesion sites at a time to the radiologist. Thus, lesion sites in areas of artifact could be rapidly discarded. The Image Gallery also produces a useful report, since it cross-references

the appearance of the lesion on virtual bronchoscopy with an "exoscopic" view of the airway anatomy. Time spent processing the virtual bronchoscopy studies (segmentation, surface rendering, and automatic lesion detection) was not included in the timings since such processing can be performed off-line by a trained technologist.

Image Gallery may also be useful for rapid evaluation of other types of virtual endoscopy, including virtual colonoscopy and virtual angiography.

ACKNOWLEDGMENT

Lynne M. Pusanik, BSME, provided invaluable programming expertise for this project.

REFERENCES

1. Marks J, Andalman B, Beardsley PA, et al: Design galleries: A general approach to setting parameters for computer graphics and animation, in ACM SIGGRAPH. Los Angeles, California: ACM pp 389-400, 1997
2. Summers RM, Feng DF, Holland SM, et al: Virtual

bronchoscopy: Segmentation method for real time display. *Radiology* 200:857-862, 1996

3. Summers RM, Selbie WS, Malley JD, et al: Computer-Assisted Detection of Endobronchial Lesions Using Virtual Bronchoscopy: Application of Concepts from Differential Geom-

etry. Presented at Conference on mathematical models in medical and health sciences. Nashville, TN, Vanderbilt University, 1997.

4. Summers RM, Pusanik LM, Malley JD: Automatic detection of endobronchial lesions with virtual bronchoscopy: Comparison of two methods, in Medical Imaging 1998: Image Processing. San Diego, CA. SPIE, 3338, 1998 (in press)

5. Summers RM, Selbie WS, Malley JD, et al: Virtual

bronchoscopy of airway lesions: Early experience with computer-assisted detection of polypoid lesions using surface curvature. Radiology, 1998 (in press)

6. Wernecke J: The inventor mentor: Programming object oriented 3D graphics with Open Inventor, release 2. Reading, MA, Addison-Wesley, 1994.

7. Summers RM: Navigational aids for real-time virtual bronchoscopy. AJR Am J Roentgenol 168:1165-70, 1997