Introducing a Virtual Reality Experience in Anatomic Pathology Education

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ABSTRACT

Objectives: *A proper examination of surgical specimens is fundamental in anatomic pathology (AP) education. However, the resources available to residents may not always be suitable for efficient skill acquisition. We propose a method to enhance AP education by introducing high-definition videos featuring methods for appropriate specimen handling, viewable on two-dimensional (2D) and stereoscopic three-dimensional (3D) platforms.*

Methods: *A stereo camera system recorded the gross processing of commonly encountered specimens. Three edited videos, with instructional audio voiceovers, were experienced by nine junior residents in a crossover study to assess the effects of the exposure (2D vs 3D movie views) on self-reported physiologic symptoms. A questionnaire was used to analyze viewer acceptance.*

Results: *All surveyed residents found the videos beneficial in preparation to examine a new specimen type. Viewer data suggest an improvement in specimen handling confidence and knowledge and enthusiasm toward 3D technology. None of the participants encountered significant motion sickness.*

Conclusions: *Our novel method provides the foundation to create a robust teaching library. AP is inherently a visual discipline, and by building on the strengths of traditional teaching methods, our dynamic approach allows viewers to appreciate the procedural actions involved in specimen processing.*

Anatomic pathology (AP) residents enter the dynamic and hectic practice of surgical pathology with minimal exposure to surgical pathology during medical school—in some cases having never touched a microscope[1,2]—yet they are swiftly presented with the daunting task of properly handling and processing gross surgical specimens.[3]

Junior (postgraduate years 1-2) AP residents are traditionally introduced to gross processing techniques by senior residents, pathologists' assistants, or attending pathologists, commonly in the form of verbal instructions, which are not standardized in their delivery. This teaching method follows the "see one, do one, teach one" mantra of experiential education[4] and is generally supplemented by locally maintained or commercially available manuals of surgical pathology procedures.[5-7] The mantra of AP education is challenged when applied to the rigors of modern health care systems, which are usually busy and plagued with increasing workloads, limiting the availability of senior personnel to teach.[8] Another notable barrier to education is the fluctuation of specimen complexity among different institutions.

Attempts have been made to overcome limitations of AP education, wherein residency programs have implemented "boot camps" that introduce, among other things, basic gross dissection skills. Unfortunately, less than half of surveyed residency programs report having such a curriculum.[2] Aware of these limitations, we set out to develop the foundation for a system that upgrades the teaching methods of proper surgical specimen processing. We created and tested a high-definition (HD) video library, focused on the fundamentals of gross specimen examination—orientation, description, dissection, and sampling[3]—viewable on two-dimensional (2D) and three-dimensional (3D) platforms and optimized for virtual reality (VR) applications. The content was built as an entirely immersive environment with active-learning simulations, complemented by instructional audio voiceovers that provide processing guidance and highlight clinically relevant aspects for different specimen types.

To our knowledge, we present the first published report in the English literature describing this novel teaching method in surgical pathology, analyzing the impressions and possible physiologic effects of junior residents who experienced it.

Materials and Methods

Two commercially available HD camcorders were housed in a stereo camera system with a 33.5-mm intra-axial distance from the center of the right (primary) and left (replica) lenses. The paired cameras used a primary/replica communication protocol to synchronously record specimens processed by senior residents and an attending pathologist following standard operating procedures. Oriented to realistically capture the prosector's point of view, adjustable mounts adhered the system to a gross station benchtop at a predetermined height from different specimen types **Figure 1**. The backdrop was composed of a white surface to reduce background distractions and a fixed 15-cm ruler to provide the viewer with an approximate scale for every frame. Three formalin-fixed specimens were chosen based on how frequently they are encountered in our daily practice (benign hysterectomy, breast lumpectomy) and complexity of dissection (postmortem brain with the cerebral arterial circle). A live video stream of the recording process was transmitted via the primary camcorder's built-in Wi-Fi network that is password protected using industry standard encryption to a receiving mobile app on a tripod-mounted smartphone. The transmission was used by the prosector to monitor the recording session and control the camcorder's settings.

The video files were shot at 59.94 frames per second, with a video resolution of 1080p, and horizontal fields of view ranging from 64.6 to 94.4 degrees. The 2D content was generated using footage from the viewpoint of the primary camera while the stereoscopic 3D videos simultaneously presented the primary and replica viewpoints side-by-side to achieve stereopsis **Figure 2**. Raw video files from each camcorder were converted to head-tracking capable stereoscopic 3D, for VR simulations, with adjustments to the horizontal and vertical convergence to obtain a desired depth of field. Instructional audio voiceovers were created using a USB microphone, containing three condenser capsules, and open-source audio recording software. Following contrast and color-level adjustments, speed

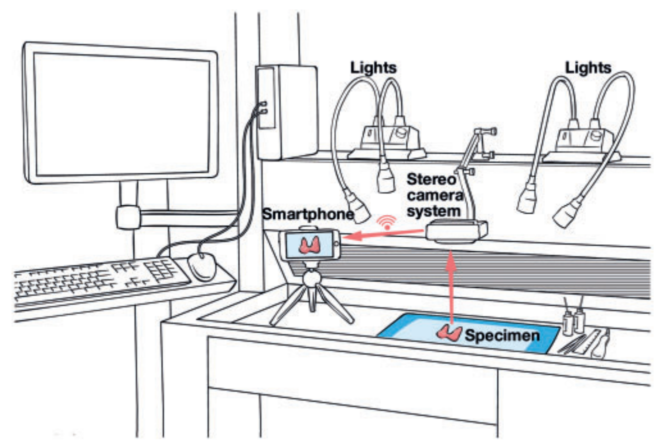

Figure 1 A modified gross station with video recording rig. Two battery-operated high-definition camcorders are housed in a stereo camera system, using a primary/replica communication protocol, and mounted at a predetermined distance from gross specimens. The video capture is monitored with a tripod-mounted smartphone via a video transmission using the primary camera's built-in Wi-Fi network. Printed with permission from Mount Sinai Health System.

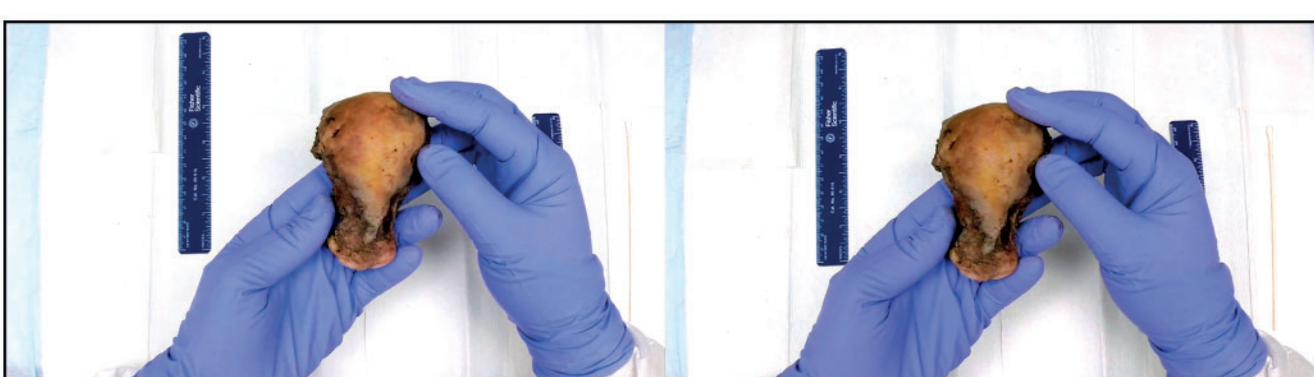

Figure 2 A representative screen capture of the stereoscopic three-dimensional video in 16:9 aspect ratio, showing the gross evaluation of a benign hysterectomy specimen.

modifications, and integration of audio and complementary multilingual subtitles, the videos were exported with a 16:9 aspect ratio. Finalized 2D and 3D videos were identical in duration and content, differing only in the displayed format. Video files were stored on a local workstation and smartphone with full disk encryption.

Nine junior AP residents experienced the three videos once in 2D on a 22-inch full-HD monitor and again in 3D on the 5.7-inch HD display of a smartphone contained in a head-mounted display (HMD). All videos required the use of over-the-ear headphones for the audio commentary. To best counterbalance the study, a crossover study design was modeled, in which participants were alternatively assigned to one of two viewing sequences: 2D first and then 3D or 3D first and then 2D. To reduce possible carryover effects from one viewing condition to another, residents were given an estimated 4- to 5-minute interim washout period with no simulation exposure. Participants gained video player control, including the ability to pause, forward, and rewind as desired, by using a Bluetooth computer mouse or gamepad for the 2D or 3D experience, respectively.

To address concerning consequences as a result of viewing 3D media, self-reported motion sickness data were collected by the standardized Simulator Sickness Questionnaire (SSQ) at baseline, following the first simulated experience, and one last time after the second set of videos.[9,10] The SSQ is composed of a 16-symptom checklist, each rated from 0 to 3, and the SSQ score is the sum of these scores multiplied by 3.74. An SSQ score of less than 5 indicates symptoms are inconsequential while a score greater than 20 suggests discomfort, and we hypothesized simulator sickness would increase during exposure to our content, particularly when experienced in stereoscopic 3D. Resident participants with a baseline SSQ score greater than 20 were excluded from the study, as measurements are only reliable for healthy individuals.[11] The educational value, level of interest, utility, and opinions of the different viewing technologies were assessed by Likert scale questions. Statistical analysis was performed using SPSS Statistics version 22.0 (SPSS, Chicago, IL).

Results

A total of three unique surgical specimens were recorded in MP4 format, and the unedited content amounted to 23.83 gigabytes (GB) of disk storage. Once edited for time and combined with WAV audio files, the processed 2D and stereoscopic 3D videos occupied a total of 9.48 GB, with a total running time of 12 minutes and 44 seconds **Table 1**.

Nine junior AP residents participated in the study and viewed the 2D and 3D videos, for a total exposure time of 25 minutes and 26 seconds. Residents provided SSQ scores at baseline, after the first set of videos, and at the end of the experimental session. A repeated-measures analysis of variance (ANOVA) was conducted on the three SSQ scores to examine how simulator sickness differed between time points. Of the nine participants, one resident had an elevated baseline SSQ score of 41.14 but did not drop out of the study. However, the resident was ultimately excluded from the SSQ statistical analysis. Although there was an increase in mean SSQ scores during the experimental session, the ANOVA revealed no significant effect on SSQ scores, $F(2, 14) = 3.89$, $P = .62$.

A paired samples t test was performed to determine possible differences in simulator sickness ratings between 2D videos (mean [SD], 8.42 [2.62]) and 3D videos (mean [SD], 17.30 [4.89]), which were not significant, $t(7) = -1.70$, $P = .13$. With four participants first encountering the 2D content while the other four experienced the stereoscopic 3D videos, additional analysis was conducted to uncover possible carryover effects of viewing order. An independent samples t test for post-2D video scores, $t(6) = -2.24$, $P = .07$, and a separate independent samples t test for post-3D scores, $t(6) = 0.45$, $P = .70$, showed no significant difference between the two condition assignments.

All of the nine residents, including the resident excluded from the SSQ analysis, responded to a postexperimental questionnaire, in which 100% stated they would use a gross video library in preparation to examine a new specimen type

Table 1
Gross Processing Videos Used in the Study and Disk Storage Occupied, Arranged by Specimen Type

Specimen Type	Duration of Unedited Videos,[a] Minutes:Seconds	Size of Unedited Videos,[b] GB	Duration of Edited Videos,[c] Minutes:Seconds	Size of Edited 2D Videos, GB	Size of Edited Stereoscopic 3D Videos, GB
Benign hysterectomy	15:14	6.69	4:41	1.77	1.77
Breast lumpectomy	12:49	5.66	3:30	1.30	1.30
Postmortem brain	49:30	11.48	4:33	1.67	1.67
Totals	77:33	23.83	12:44	4.74	4.74

GB, gigabyte; 2D, two-dimensional; 3D, three-dimensional.
[a]Video footage from the primary camera.
[b]Sum of unedited videos from both the primary and replica cameras.
[c]Duration of either 2D or stereoscopic 3D video.

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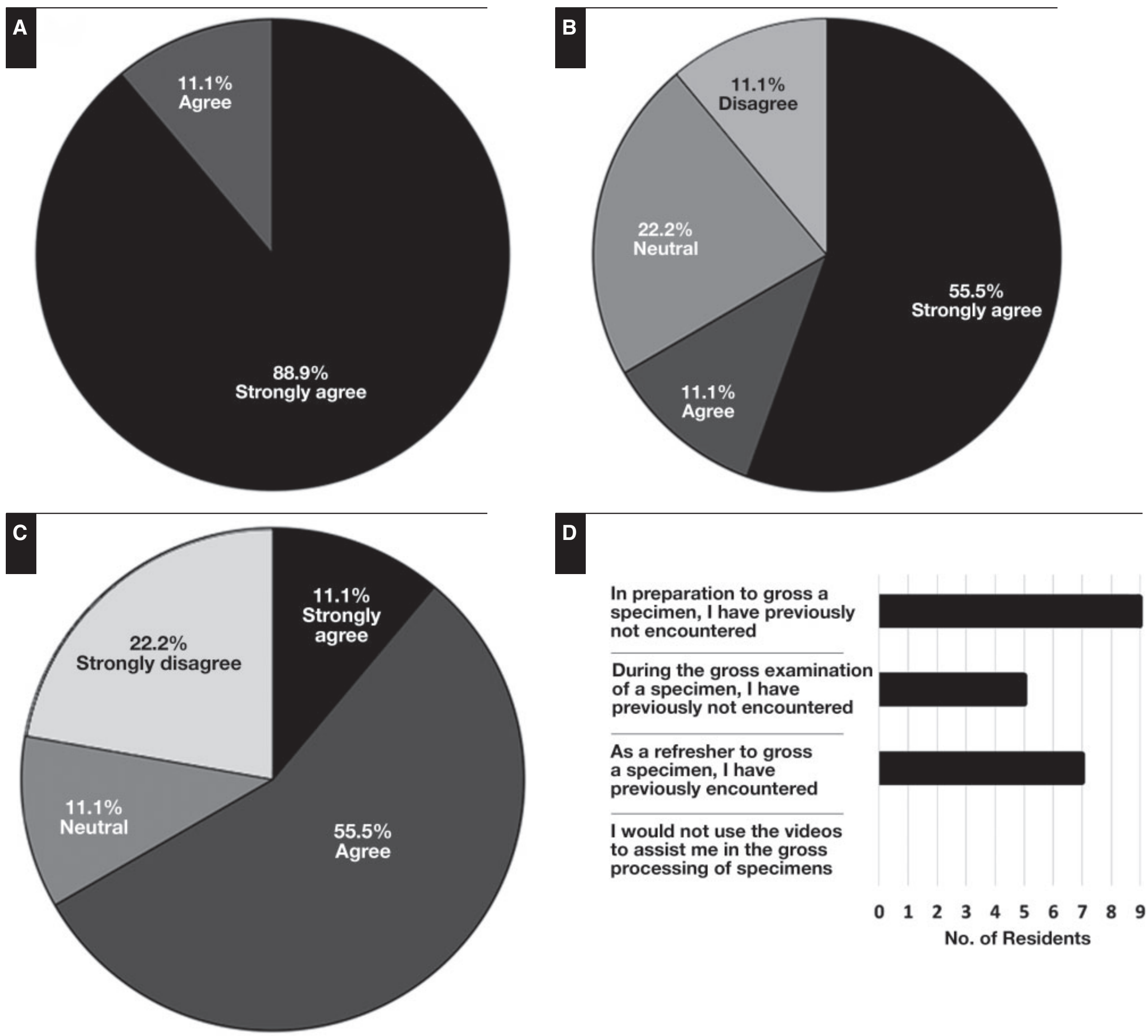

❚Figure 3❚ Likert scale responses from the postexperimental questionnaire taken by junior residents (n = 9). **A**, "I would prefer to watch gross processing videos prior to examining a specimen for the first time." **B**, "I am excited about the possibilities of 3D technology being applied to pathology training." **C**, "The 3D videos improved the overall viewing experience." **D**, Self-reported scenarios in which junior residents would view the videos. 3D, three-dimensional.

and found them useful; 55% stated that they would access the videos during the gross examination of a previously encountered specimen type. Eighty-eight percent of residents agreed that the instructional videos improved their confidence in examining breast lumpectomy, benign hysterectomy, and postmortem brain specimens. When asked about 3D technology, 67% claimed to be interested in its application to pathology education, while 55% believe that 3D improved the overall viewing experience. Residents were also given the chance to state their preferences on how they would prefer to access the videos, and 78% would like to have access to the videos from a personal device **❚Figure 3❚**.

Conclusions

The reader is encouraged to watch sample clips of our videos in 2D at https://vimeo.com/pathology/2d and in stereoscopic 3D at https://vimeo.com/pathology/3d, using "AJCP2016" as the password. Either an HMD or stereoscopic glasses will be necessary to experience the 3D clip.

Surgical pathology is intrinsically a visual discipline, but to date, a realistic simulation detailing the procedural actions and nuances of gross specimen handling from the prosector's perspective has not been described. Endeavors demonstrating surgical pathology techniques have been attempted and

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suggested, but none created immersive simulation environments, evaluated physiologic alterations of its users, or explored methods for enhanced interactivity.[2,5,12,13]

Practicing with current guidelines is a cornerstone of pathology, the scope of which is frequently updated. At the time of writing this report, a new edition of the AJCC Cancer Staging System was also in preparation, and several cancer protocols have been revised within the past few months. The leading manuals describing gross surgical procedures and numerous organ-specific gross dissection reviews predate the aforementioned changes, illustrating the limitation of text-based resources to retain currency.[14-17] An advantage that our digital content offers over physical resources is our proposed web-based delivery method. It is self-evident that digital formats are adept for frequent revisions and instantaneous distribution, whereas printed text involves the laborious process of printing and physically distributing the content. These challenges disincentivize printing manuals, and thus they may remain unchanged for many years, even decades.

The teaching videos, accompanied by textual outlines of procedures and multilingual subtitles, are intended to be accessible from standard workstations and mobile devices. The postexperimental questionnaire provided positive feedback on the utility of the videos, and a majority of the surveyed residents preferred to access the content not only during specimen processing but also outside of the laboratory on their personal devices or in large-format displays as a way to review or prepare. We propose that on-demand access to the video modules is advantageous over real-time instructions—which may be variable from instructor to instructor and from instance to instance—because of the standardized nature of prerecorded material.

Shortly after analyzing the data for this report and noticing the acceptance of our proposed teaching method by junior residents, we proceeded to create additional content to build the foundation of an instructional video library. We have expanded the collection by 14 videos to include the gross processing of a postmortem laryngectomy, radical nephrectomy, simple prostatectomy, thyroidectomies (lobectomy and total), and variations of hysterectomies and breast lumpectomies. In addition to maintaining a current library, we want to further develop the interactivity of our immersive environment. One possibility is to employ ray-tracing techniques to produce photorealistic gross specimen models, providing users the opportunity to "mock gross" any specimen type, at no risk to the patient. These computer-generated models are created by tracing the path of light through pixels in an image plane and later simulating interactions as virtual objects.[18] Photorealistic methods have been explored in clinical and surgical settings[19] and forensic pathology,[20] and they are even becoming commercially available for surgical pathology. In addition, the full potential of the video library can be achieved by making the 2D content available within the gross laboratory. Noting precautions that have previously been published regarding the access of instructive information in biohazardous environments,[21] we intend to integrate our method at each gross bay, enhanced by interactive checklists to ensure proper specimen sampling.

By building on the strengths of conventional teaching methods, we successfully created concept-oriented material of utmost quality, capable of accurately detailing specimen subtleties, as a model for active-learning simulations to develop solid working knowledge of surgical pathology. It is our goal to maximize meaningful contact hours with gross specimens when traditional shoulder-to-shoulder observational opportunities are not possible. Our method will not only enhance efficiency during AP rotations but also promote successful progression of residents by benchmarks recently outlined by the Pathology Milestones Working Group.[22] This teaching format, whether viewed in standard 2D or experienced in stereoscopic 3D, will have a positive effect on the learner beyond what is capable of being explained with verbal instructions, texts, illustrations, and photographs. When surveyed, junior residents were very receptive to the 3D videos and were excited about the possible directions the technology may go, particularly as it applies to medical education. Filming and postproduction revealed limitations to the implementation of our method. A laboratory without experience in cinematography, editing of audio and video, and basic virtual reality will have to overcome a significant learning curve. The production also requires investment in camcorders, digital storage, head-mounted displays, and allocation of full-time equivalents.

Regarding viewing simulation content in 2D and stereoscopic 3D, our hypothesis that simulator sickness would increase was ultimately rejected. Although the average SSQ score did increase with time, statistical analysis does not suggest significance. The scores immediately following the 2D and 3D videos did not statistically differ regardless of the viewing order, rejecting the hypothesis that 3D videos would induce greater simulator sickness. Interestingly, one of eight residents had an SSQ score indicative of discomfort after viewing the 2D video (SSQ = 22.55), while two residents reported an SSQ score indicative of discomfort following the 3D videos (26.18 and 44.88). However, there were no voluntary dropouts or worrisome complaints in our postexperimentation survey. Several larger studies, investigating the effects of VR content, have shown that 3D content can induce motion sickness.[9,11] We did not observe this side effect, and we attribute it to shorter VR exposure times and stationary footage.

Improving patient safety remains the main point of interdisciplinary education,[23] and our true-to-life approach

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to gross specimen processing has much to offer to other medical specialties. At our institution, neurosurgery residents and surgery fellows in both breast and transplant programs are required to complete a surgical pathology rotation as brief cross-specialization exposure.[24] The intent is to expose resident surgeons to the practices within the AP laboratory, allowing them to gain an appreciation of how their actions in the operating room have downstream effects on the specimen and subsequent tumor staging. Residents of multiple surgical specialties have used virtual simulations and instructional videos for successful skill acquisition with minimal costs and fewer risks to patient safety than traditional teaching methods.[25,26] In this manner, we seek to bridge the gap between surgery and pathology and strive for the common goal of optimal patient care.

This report is the first description detailing the creation and analysis of a simulated teaching method for surgical pathology. Further studies assessing the educational value and practice impact of these methods are needed. Adequate gross specimen examination remains a pivotal component in a patient's clinical outcome. Thus, similar to cancer protocols, which provide revised resources and references for complete reporting of malignant tumors, 2D and stereoscopic 3D video libraries can become a cornerstone in standardizing surgical pathology practice.

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