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Introduction
A broad definition of "serious games" includes software applications that utilize gaming design and technology for the primary purpose of educating users. Serious gaming in medical education is emerging, and the literature suggests that the inherently interactive nature can improve the efficiency of learning and retention rate. Serious games are being actively explored as supplements to and, in some cases, replacement for traditional didactic lectures and computer-based instruction in venues ranging from medicine to the military.2,3

Serious games on the PC platform, due to wide availability and ease of use, can provide a smooth transition point to learning more sophisticated virtual-reality systems. There has been a recent push in surgical specialties to incorporate virtual-reality simulation into residency programs.2

Purpose and Methods
Our objective was to develop an interactive computer simulation of complex structures of the head and neck that would assist the teaching of relevant anatomy and pathology, especially of the middle ear and the pterygopalatine fossa due to their three-dimensional complexity in structure and connections to surrounding anatomic spaces.

Areas of the head and neck with complex spatial relationships were selected and their anatomical relationships were confirmed. Graphical representations of these areas were created performed and integrated into a virtual gaming environment through various software components. A variety of adjunctive teaching materials were also developed and laid over this virtual environment to reinforce the complex relationships.

Results
A 3D simulation was successfully created which allows users to freely move throughout a virtual environment framed by key and complex anatomy of the head and neck. Both this movement and visualization of the environment in all directions is provided through simultaneous use of the mouse and keyboard. Navigation through the game-space is assisted by a dynamically updated "anatomical" compass. A combination of accurate structural depictions and conceptual representations of cavities and spaces with rooms, hallways, doors and/or windows was employed. Structures can be identified and educational information through adjunctive media can be displayed with simple point-and-click techniques. Gaming features were also employed to provide entertainment value with the expectation that this would reinforce the anatomical concepts.

In more detail, users are able to identify each anatomic structure by name as well as to zoom on, shoot at, or project certain entities onto the structure. Pop-up menus are used to provide information and images about the pathology of the target structure. Animated bacteria and viruses were also developed to serve as the "enemy." This high degree of interactivity with the addition of the gaming features may promote learning and improve retention rate.

Conclusion
Virtual simulation of the complex anatomy of the head and neck may be an effective means to offset the cost and limited availability of cadaveric dissection. We describe here the development of such a simulated environment employing an interactive gaming construct which, to our knowledge, has not been previously described elsewhere.

Some anatomic structures in the head and neck can be difficult to envision in their proper spatial orientation and whose functions are complex. To our knowledge, our gaming design in its entirety has not been previously described in the medical literature. Our future plans include incorporating the Wii controller in the game, designing further anatomical details, adding more flash tutorials and quizzes, providing 'challenges' or 'missions' within the game-play, as well as simulating basic endoscopic and interventional procedures in order to give users the ability to manipulate and change the game's 3D world and target objects.

References

Figure 1: Bacterial shooting at ear causing damage represented by reduction in "hit points." Blue transparent bones represent entry points to the skull.

Figure 2: Three-dimensional map of the gaming environment.

Figure 3: Outer ear with markings from bullet and anatomical compass.

Figure 4: Pterygopalatine fossa and ganglion, infratemporal fossa and orbit, ganglion further ahead, midline inset on left, palatine canal on bottom, pharyngeal canal on right, and pterygoid canal containing deep petrosal nerve.

Figure 5: Stapes, incus, malleus, chorda tympani nerve, tympanic nerve, extratemporal tube, anterior wall of middle ear (see complete).

Figure 6: Rounded temporal, stympatic canthals, internal angular vein, internal carotid artery and sympathetic plexes, anterior, unindexed. Jinguo facem, CN.E.