Assessing Portal Design Skills in the Radiation Oncology Interactive Case Management Examination

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The American Board of Radiology is developing a computerized interactive case management examination to be used to evaluate the clinical skills of radiation oncologists. In the past, these skills have been evaluated by a pencil and paper written examination and an oral examination. With the increasing capabilities of computers, these skills can be easily, and perhaps even better, evaluated digitally. The aim is to develop an examination, which will be based on actual clinical cases, and be interactive so that it better mimics the clinical practice of a radiation oncologist than a written examination. It will also be less labor-intensive and less expensive than an oral examination. One of the most important skills of a radiation oncologist is the ability to design treatment portals that will encompass the entire cancer and yet minimize the irradiation of critical tissues and normal organs. Important parameters for radiation oncologists include the direction of the treatment beam, the size and shape of the portals, and the location of the margins of the field relative to patient anatomy and tumor location. In order to evaluate a physician's ability to design treatment portals, the computer-based examination has the capability to interactively construct field lines. The computer interface allows the candidate to draw field lines on a digitized x-ray image in a manner similar to practice. After the candidate illustrates the field lines, the evaluation of the response must be performed quickly to avoid interrupting the flow of the examination. The answer key is stored as a lossless compressed image. The key contains three regions consisting of (1) the must-include region, which contains the tumor; (2) the must-exclude region, which contains tissues that if damaged would affect patient vitality and quality of life; and (3) the envelope of acceptable curves. Each region is assigned a unique byte code. The candidate's response is assigned a fourth byte code. Using basic logic operations, the response is swiftly evaluated. The scoring algorithm scores a candidate's action as correct if his/her drawn area encompasses all of the "must-include region" and is within the "envelope of acceptable curves." It scores a candidate's action as incorrect if his/her drawn area overlaps any part of the "exclude region" and/or exceeds at any point the "envelope of acceptable curves."

THE AMERICAN Board of Radiology is developing a computerized interactive case management examination to be used to evaluate clinical skills of radiation oncologists. In the past, these skills have been evaluated by a pencil and paper written examination and an oral examination. With the increasing capabilities of computers, these skills can now be easily evaluated digitally.[1] The purpose of this report is to describe how a computerized interactive case management examination would be configured and to describe the potential advantages of such an examination for radiation oncology certification.

Radiation oncologists must pass two examinations to be certified as having achieved a certain level of proficiency: a written examination and an oral examination. The written examination is designed to test cognitive knowledge (ie, memorized facts) in areas such as basic science, pathophysiology, disease processes, clinical syndromes, and the specific results of clinical trials. The oral examination is designed to test the candidate's clinical skills, eg, to show whether the candidate can perform an appropriate pretreatment clinical evaluation, compose a satisfactory overall treatment program, present a reasonable treatment plan for the radiation therapy portion of this overall program, and demonstrate adequate knowledge of the results and complications that might be expected from treatment.

The written examination is comprised of three 4-hour examinations, one each covering physics, biology, and clinical oncology. It is made up of true-false (X-type), multiple choice (A-type), and matching (B-type) questions. Each examination has 350 to 425 scorable units. Candidates must pass the written examination to be eligible to take the oral examination.

The oral examination is comprised of eight 30-minute interactive examinations by physicians who are especially knowledgeable in the specific category. The categories include gastrointestinal cancers; gynecological cancers; genitourinary cancers;

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cancers of the reticuloendothelial system; head, neck and skin cancers; breast cancer; central nervous system and pediatric cancers; and lung, mediastinum, soft tissue, and bone cancers.

The written examination is an effective and reproducible examination. It is an effective way of evaluating the candidate's knowledge of clinical oncology, biology, and physics. However, it is not a case management examination. Therefore, it is not a test of what a radiation oncologist does every day in his/her practice. Similarly, it is not very effective at evaluating the candidate's deductive reasoning abilities or his/her communication skills.

The oral examination is a case management examination. Therefore, it is more like the real clinical situation. It tests the candidate's deductive reasoning skills, and to some extent, his/her communication skills. It is also useful for evaluating performance in areas that cannot be assessed on a written pencil and paper examination. These include items such as the ability to delineate the extent of the tumor on radiographs or physical examination, outline target volumes, design treatment portals, describe the technical details of treatment, and select isodose curves.

The oral examination is a good examination. There is usually a good agreement between examiners, and the results tend to be reproducible. The results on the oral examination also correlate well with the results on the written examination.

Nevertheless, the oral examination does have some shortcomings. It is a subjective examination, and there is relatively little time for each category examination. Most examiners can cover only three to four cases, so the sample size is small. There can also be differences in the way the examiners grade. The board makes a big effort to educate its examiners and keep grading uniform, but there are certain to be some differences. Personality differences can also enter in. Again, the board tries to minimize this through examiner education, but there may be some differences. Finally, the oral examination process is very labor-intensive and costly. The American Board of Radiology has to bring in 60 examiners to Louisville each year to deliver the radiation oncology oral examinations.

Most of the shortcomings could be removed if you could take the "examiner" out of the picture. A digital interactive case management examination is a way of doing that. The prototype interactive examination differs from the written examination in that it is a case management examination. It differs from the oral examination in that it is more objective than the oral examination because the answers are determined ahead of time. It is also more convenient, because it can be given more often and in multiple locations. It is much less expensive than the oral examination, because it does not require examiners traveling to administer the exam and there are lower travel costs for the candidates.

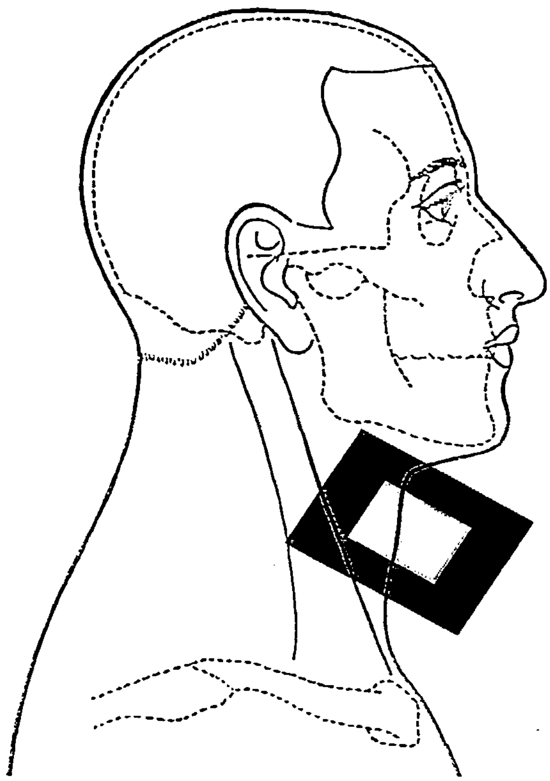

Fig 1. Portal treatment field. The light grey rectangle represents the area that must be treated and is encoded by (01). The dark grey rectangle shows the acceptable range and is encoded by (00). The remainder of the image is the external boundary that is not to be irradiated and is encoded by (10).

With the digital interactive case management examination, candidates interact with the computer just like they would with the examiner—outlining the tumor, prescribing a tumor dose, pointing to an anatomical structure, or drawing a treatment portal. They are also asked to evaluate dosimetric plans to improve the quality of the treatment delivered. There are uncued questions, which are usually referred to as "fill in the blank" questions, and there are branching questions, which are questions with several answers that can lead to different lines of questions. The increased examination expectations demand more sophisticated scoring algorithm. The scoring algorithm for drawing a treatment portal is detailed below.

METHOD

The scoring algorithm for drawing the portal treatment compares the candidate's response to an answer key. The answer key is a map of pixels that is registered to the image containing the region of treatment. The key contains the following three regions: (1) the tumor region, (2) the allowable variance, and (3) the external boundary. The region that includes the tumor must be totally included in the candidate's response. If any of this region is omitted, the candidate has not managed the case properly and the answer is scored as incorrect. The external boundary demarcates space that should not be irradiated. It could include critical structures such as the spinal cord, which if treated could leave the patient paralyzed, the kidneys, which could lead to renal injury, or a large volume of other normal tissue, which could lead to other damage or possibly even radiation-induced cancers. The area between the tumor region and the external boundary is the acceptable range of response from the candidate.

The written exam committee creates the answer key by drawing the tumor and external boundary regions on the answer key with custom-designed annotation software. The annotation software is similar to a paint program. The region of the image containing the tumor is highlighted with a red transparent accent to designate the area that must be treated with radiation. In a similar fashion, the area that should be excluded from irradiation is painted with a transparent blue highlight. The acceptable range is left untouched. By highlighting the image instead of obscuring it, the examination preparer retains a frame of reference within the image thus avoiding a tedious changing between the raw and annotated images. Selecting the regions of treatment and omission allows optimal flexibility for portal design considerations including the capability of multiple treatment regions.

After the appropriate regions are drawn, the pixel values in each region are represented with a simple binary code. The tumor region is encoded by 01, the external boundary is encoded with 10, the acceptable response is encoded with 00 and the candidate response is encoded with 11. The candidate's response is scored according to the following equations.

$$T_R = \sum_{ij} (R(i,j) \text{ AND } (A(i,j) \text{ AND } (01))) \qquad \text{(Equation 1)}$$

$$T_A = \sum_{ij} (01) \text{ AND } A(i,j) \qquad \text{(Equation 2)}$$

$$T_E = \sum_{ij} A(i,j) \text{ AND } (R(i,j) \text{ AND } (10)) \qquad \text{(Equation 3)}$$

Where i and j are indices which range over the image, AND is the binary logic operator,[2] (01) and (10) represent binary pairs, R(i,j) is the candidate's response, A(i,j) is the answer key, T_R is the area of the candidate's response that coincides with the region that must be included, T_A is the total area that must be included, and T_E is the area of the response that coincides with the region that must be excluded.

Equation 1 is used to compute the amount of the tumor area the candidate included in the response. The total T_A in Equation 2 is the area that must be included in the response. Since the area is known before the examination, the right hand side of Equation 2 is calculated prior to the occurrence of the examination. T_R must be equal to T_A to obtain a passing score. If T_R is less than T_A then part of the treatment area was left out. If T_E does not equal 0 then part of the region that must be excluded was included and the candidate will not receive a passing score.

Currently, only a two-digit code is necessary to evaluate the candidate's performance. If examination requirements change, the current design has flexibility to expand adding opportunity for more sophisticated evaluation.

The answer key will be stored as a run-length encoded bitmap (RLE). RLE is a loss-less image compression scheme that works well with images that contain large regions of the same value. The image dimensions are commonly 1k × 1k. Using standard RLE that includes a header of about 350 bytes, approximately 60% of the image lines will be encoded by 8 bytes. The remaining 40% of the lines will be encoded by either 6 or 8 bytes (or on average 7 bytes). With these estimations the typical image will compress by a factor of 126:1. Customized RLE would surpass this result but it is not deemed necessary at this juncture.

The examination software was written using Microsoft (Redmond, WA) Visual C++. A second experimental interface was also developed in JAVA for a future possibility of allowing the exam to be taken over the Internet. The examination is administered on Windows 2000 workstations (Microsoft). Currently, the examination workstations have 128 MB of RAM, 6 GB of hard drive space, 100 Mb/s network, and display capability with resolution of 1,600 × 1,200 and true color on 19-inch color monitors. The examination material is loaded on each workstation from a server. The server has 512 MB of RAM, a redundant array or inexpensive disks (RAID) with 18 GB of space, and dual 333-MHz processors. The server also has the additional responsibilities of scoring the examination and storing a redundant copy of each of the candidates' responses.

CONCLUSION

The computerized interactive case management examination will be pre-tested in April 2001, in conjunction with the next administration of the recertification examination (now called maintenance of certification or MOC) in radiation oncology. Candidates for this examination are practicing radiation oncologists who wish to demonstrate their continued competence by passing periodic examinations. The current MOC is comprised of true-false (X-type), multiple choice (A-type), and matching (B-type) questions, which are presented in a computer format, but previously were used in a paper and pencil examination. The pre-test of the interactive examination will allow the board to compare the performance on both formats, ie, a computer application with the old paper and pencil examination.

The ultimate role of the computerized interactive case management examination is yet to be determined. While it is currently being tested in the MOC situation, it will probably be applied to the certification examination process at some time in the future. The goal is to use it to replace part or all of the oral examination for certification and MOC in radiation oncology. While these are already assessed well by the paper and pencil examination regardless of whether it is administered on paper or in computer format, the computerized interactive examination is much more effective in evaluating deductive reasoning. The question is, is it as effective as an oral examination? It is certainly cheaper. It also has multiple advantages over the oral examination in that it removes the concerns about personality conflicts and it can be delivered in multiple locations, at multiple times, throughout the year.

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