Importance of virtual reality simulators in interventional radiology: the ImaGiNe-S CIRSE 2008 experience

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1. Purpose

AIM:
To determine face and content validity of a physics based virtual reality interventional radiology simulator, Imagine-S (Imaging guided interventional needle puncture simulation).

BACKGROUND:
Image-guided needle puncture procedures are commonly performed in interventional radiology (IR) and use hand-eye coordination to direct needles to perform biopsy, nephrostomy and abscess drainage.
Currently, the perceptual-motor skills required are learnt in a traditional apprenticeship model, with drawbacks such as involvement of patients, limited case mix and reducing in-hospital work hours of trainees. While animal and fixed models can reproduce many training objectives, they are an imperfect substitute for the 'real patient' experience.
Computer based VR simulators can generate variable virtual environments from imaging data with stereo 3D visual presentation and devices to convey feel, realistically mimicking procedures on patients. Application of such simulations to training requires evidence of efficacy.
ImaGiNe-S is a computer-based VR training simulator, using virtual environments with stereo 3D visual representation and devices to convey feel, realistically mimicking a percutaneous nephrostomy procedure. Use of such simulator to train IR requires evidence of correct development before studies of efficacy.

TECHNICAL INFORMATION:
The simulator is composed of four components, image processing, haptics rendering, metrics processing and graphic rendering. Each module is described below:
Image processing
The patient voxel data based is used in the virtual environment. The CT scan Hounsfield units are used to compute the haptic rendering. Moreover, these data have been segmented to extract no-go areas. These two voxel data are used in the simulator either for the haptic rendering of for the metric measurement.

Haptic rendering
The haptic rendering is processing the ultrasound probe and the needle separately. On the one hand, a force response is given when the probe is touching the skin to have a stiff contact so it cannot penetrate the body, at the same time it triggers the ultrasound rendering based on the position and direction of the probe. On the other hand, the needle could penetrate the skin a force feedback is rendered based on the gradient of the voxel the needle is going through.
Metric processing
The simulator provides the user with information about his performance on the simulator. While inserting the needle, a red triangle is displayed showing if the user is touching a no-go area. In the same way, a message is displayed when the target has been reached.
Graphic rendering
The external skin of the patient is rendered in 3D by using specialised glasses. A 2D simulated ultrasound is generated by using CT scan data. Noise and bone shadowing have also been added.

TASK ANALYSIS:
Accurate simulation requires incorporation of data from procedural task analysis into the development phase, including critical procedure steps and their metrics for objective measures of operator competence.

VALIDATION:
Correct reproduction of the simulator task and appropriate fidelity are the cornerstone of producing a simulation that has relevance to a particular training objective.
Face validity is the extent to which the simulation appears to be a correct representation of the real world task.
Content validity is the degree to which an expert judges the simulator as correctly replicating the physical processes of the real world task.
In our study, validation draws on the teams' occupational psychology expertise, along with évaluation by clinical radiologists.

BENEFITS:
Evidence to support the use of VR simulator training and assessment of IR skills could, as an end result, shorten the early learning curve, remove basic skills training from patients, improve safety and efficiency in the NHS, reduce the time to attain and maintain competence, and provide evidence for accreditation and revalidation.

2. Material and Methods
Local research ethics committee and research governance approvals were sought for a pilot study to carry out face and content validation of Imagine-S.
A prospective study was carried out at the CIRSE conference, Copenhagen 2008.
53 subjects used the Imagine-S simulation to perform simulated percutaneous nephrostomy task. Subjects then completed a 5-point Likert scale questionnaire to assess face and content validity (where 1scored = not realistic at all; 3 scored =averagely realistic; and 5 scored =very realistic).

3. Results
53 participants filled out qualitative questionnaires (92% male and 8% female; 56%

trainees and 44% subject matter experts SMEs).
Outcomes for face validity showed the following:

- 44% participants thought that the design of Imagine-S was averagely realistic; 32% rated it as moderately realistic
- 44% participant rated realism of procedure as averagely realistic with a mean score of 2.9/5
- 40% participant rated response to manipulation of probe, ultrasound image and depth
- perception as averagely realistic

Outcomes for content validity were rated as moderately average for all critical task steps.

- Use of image guidance to identify the collecting system scored poorly with a third of participants rating it as moderately realistic, and another third rating it as moderately unrealistic. This discrepancy was due to the confusion caused in locating the renal collecting systems which appeared as bone density due to data segmentation errors from contrast CT images.
- 50% participants found the optimum position for puncturing and entering the collecting system to be moderately realistic, with a mean score of 3.3/5
- 67% participants found positioning needle on the virtual patient to be moderately realistic, with a mean score of 3.3/5

44/53 (83%) participants considered Imagine-S to be a useful model for training skills for nephrostomy.

4. Conclusion

The role of virtual reality in Interventional Radiology is positive. ImaGINe-S may be used to train core skills and procedure steps.
Review by subject experts has provided invaluable information in the form of repeated face and content validations, contributing tot he re-design of each iteration and hence increasing relevance to the procedure in the real world.
From the results gathered, face validity scored in the majority as average and content validity scored as moderately realistic.
There is ongoing development still taking place. The limitations found in the hardware during this study are in the process of being addressed. The "feel" from real world data is now incorporated into the existing model. There are now improved metrics for objective assessments used for repeat validation tests including construct validation and transfer of training tests.

5. References

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