

Original Article

Three-dimensional-printed models in bladder radical cystectomy: a valuable tool for surgical training and education

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Abstract: *Purpose:* To evaluate the impact of 3D bladder models on how clinical medical students understand and learn about bladder anatomy and radical cystectomy processes during their clinical education. *Methods:* Forty-five first-year graduate clinical medical students were enrolled in this study and randomized into a 3D+CT group educated with 3D models + CT images, a 3D group educated with 3D models only or a CT group educated with CT images only. Pre/post-training testing and a third-party assessment were carried out to assess knowledge acquisition. Student feedback was measured by survey questionnaires. The results of the test, the third-party evaluation and the student feedback survey were collected and compared. *Results:* The pre- and post-training test results indicated that all three training methods had the same effect on knowledge acquisition (P value >0.05). The third-party assessment showed that the students in the 3D+CT group and the 3D group benefitted more than those in the CT group in understanding the spatial structure of the bladder and radical cystectomy (RC) processes ($P < 0.05$), but there was no difference between the 3D+CT group and the 3D group. The average self-evaluation scores in the 3D+CT and 3D groups were $20.4 (\pm 0.57)$ and $20.13 (\pm 0.53)$, respectively, while the average score was $16.8 (\pm 0.66)$ in the CT group. Physical 3D models can improve student satisfaction with surgical training. *Conclusion:* Physical 3D models can help medical students improve their understanding of the spatial structure of the bladder and help them learn bladder radical cystectomy.

Keywords: 3D printing, bladder cancer, radical cystectomy, education, evaluation, spatial structure

Introduction

Three-dimensional (3D) printing is a new technology that can be used in medical fields to assist in surgical planning, trainee/patient education, and surgical navigation. This technique is helpful because 3D printing can be used to produce 1:1 physical models based on high-resolution digital data (such as computed tomography imaging data) to accurately reveal the anatomical relationships of organs and their surrounding tissues [10-12].

Bladder radical cystectomy (RC) is a challenging operation in which medical students often experience difficulty in grasping the spatial characteristics of the bladder. Currently, conventional 2D computed tomography images are being used as medical resources in anatomical teaching; however, this approach cannot meet

the students' educational needs. Thus, 3D-printed models, which can reveal the bladder's anatomical structures and its relative spatial positioning to the pelvis, may be a good tool for students in the area of surgical education. Here, we show that 3D-printed models can improve the medical students' understanding of the characteristics of the pelvis and bladder and help with learning bladder radical cystectomy.

Materials and methods

3D bladder model structure and study design

Individualized physical 3D anatomical models were derived from contrast-enhanced computed tomography (CT) data and printed using the technique described [4]. The contrast-enhanced computed tomography imaging data were col-

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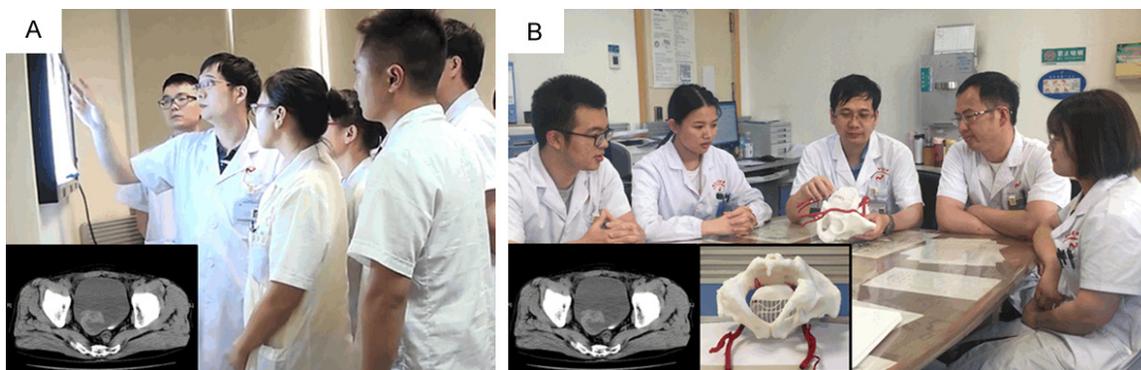


Figure 1. Training section. A. Students were provided CT images in the training section. B. Students were provided 3D models in the training section.

lected and run through the Mimics 18.0 system (Materialise, Leuven, Belgium) for 3D restructuring. FS3200PA nylon powder mixed with colorant resin was used to create the 3D anatomical models. The bladder, surrounding tissues, pelvic plexus, vessels, ureter, and posterior urethra were dyed in different hues to reveal the anatomical relationships.

Forty-five, first-year graduate clinical medical students who had previously completed an anatomy course without instruction pertaining to RC were randomly matched to RC surgical training by 3D models + CT images (3D+CT group, n=15), training by 3D models only (3D group, n=15), or control training by CT images only (CT group, n=15). All participants were given a training course (1 hour long) on bladder anatomy, treatment strategies for bladder cancer, and processes of RC by one of the two experienced surgeons who were blinded to the aims of this study. The main difference between groups, as shown in **Figure 1**, was that the 3D group was provided with only the patient's 3D models throughout the course, while in contrast, the 3D+CT group was provided with the patients' 3D models as well as CT images.

This study was approved by the Ethics Committee Board of Hunan Cancer Hospital (No. 2016[05]). All methods were performed in accordance with relevant guidelines and regulations. Written informed consent was obtained from each participant.

Training quality assessment

All students were given a pre-training test prior to the training course. The test comprised 20 multiple-choice questions covering the areas of

anatomy, surgical decision making, surgical procedures, and possible surgical complications. After the course, the students were tested on the same knowledge. All questions were rated as 0 or 1 point, in which each correct answer was given 1 point; otherwise, 0 points were awarded. The cumulative points for the pre- and post-training tests ranged from 0 to 20.

The third-party assessment

All participants were given two patient datasets to describe the anatomical characteristics and surgical processes. The patients' 3D models were provided to the 3D+CT and 3D groups, and CT imaging data were provided to the 3D+CT and CT groups. Then, the descriptions and evaluations of all students were rated by two surgeons who were unaware of which evaluations belonged to which group. The planning evaluation scores ranged from 0 (unqualified) to 10 (very good), and the overall scores ranged from 0 to 10.

Students' feedback

A questionnaire [2, 9] (**Figure 2**) was created, which consisted of open-ended questions with multiple choice responses based on a 5-point ordinal rating scale (1-strongly disagree, 5-strongly agree), and completed by all participating students. Five items were evaluated by this questionnaire.

Statistics

All data analyses were performed using statistical software (SPSS v.16.0, Chicago, IL, USA) and compared using Fisher's exact test or the

1. The training course was interactive.				
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. The instructional material was easy to understand.				
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. The instructional material improved my understanding of the bladder characteristic and anatomy.				
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. I clearly understand the processes of the bladder radical cystectomy surgery.				
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. I am confident in selecting a surgical strategy with the assistance of the provided materials.				
Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 2. Questionnaire on student feedback.

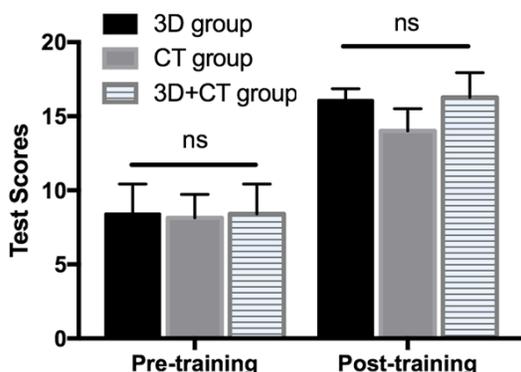


Figure 3. Results of the pre/post-training test. The students in all three groups had similar knowledge levels based on the pre-training test. Students in the 3D+CT and 3D groups had higher test scores after training (vs. students in the CT group); the difference was not statistically significant ($P>0.05$).

t-test. P values were two-sided, and statistical significance was set at 0.05.

Results

A total of 45 first-year graduate clinical medical students were enrolled in this study. Following randomization, 15 students per group were assigned to the 3D+CT group, 3D group or CT

group. All participants had the same medical education background, and the pre-training test scores showed that all three groups had similar knowledge levels of bladder anatomy and bladder cancer ($P>0.05$). While the students who trained with 3D models, including the students in the 3D and 3D+CT groups, had higher test scores after training than those who trained without models, the difference was not statistically significant between all three groups ($P>0.05$) (Figure 3).

The third-party assessment, as evaluated by urologist surgeons, showed that the students exhibited better accuracy after using the 3D models than students who only used the CT images ($P<0.01$) (Figure 4).

The self-evaluations from the student questionnaires indicated that the physical 3D bladder models improved understanding of the anatomy and characterization of the bladder and helped to more easily assess the surgical strategy for each bladder mass. Students in the 3D+CT and 3D groups reported overwhelming satisfaction with the 3D models for assistance in the training course and surgical planning. The average self-evaluation scores in the 3D+CT and 3D groups were 20.4 (± 0.57) and 20.13

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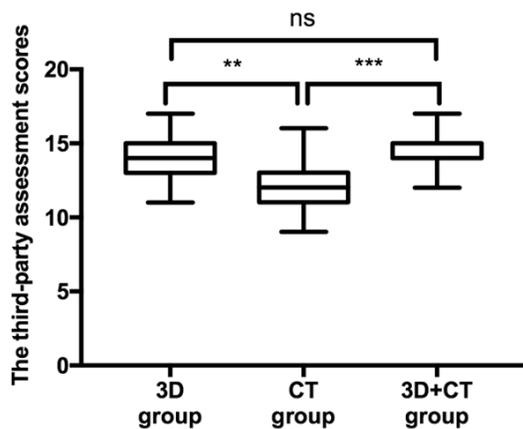


Figure 4. Results of the third-party assessment. The scores were determined by 2 experienced surgeons based on the students' description and comprehension of bladder RC following a review of the patient's clinical data. 3D models provided significant advantages in grasping the spatial structures of the bladder and surgical processes ($P < 0.01$).

(± 0.53), respectively, while the average score was 16.8 (± 0.66) in the CT group. This difference was statistically significant ($P < 0.001$) (Figure 5).

Discussion

Understanding the complex anatomical structural relationships between the bladder and its surrounding tissues is the main challenge in grasping the RC operation processes. The traditional techniques for visualization, such as cross-sectional magnetic resonance imaging or computed tomography, are too abstract, and students are easily disoriented when learning the complex anatomy [5-7]. Here, we showed that providing students with 3D bladder models during bladder radical cystectomy (RC) education was superior to traditional educational methods for the students' understanding of the anatomy, treatment options and surgical processes. This was the first study to qualify the impact of 3D models in bladder RC education.

In this study, we produced 3D bladder models and compared them to traditional 2D CT images for bladder RC education. The results of this study, which performed clinical education, provided evidence that the 3D models did not have significant advantages in furthering the students' surgical knowledge compared with traditional CT images after surgical training; all students had the same knowledge levels in the

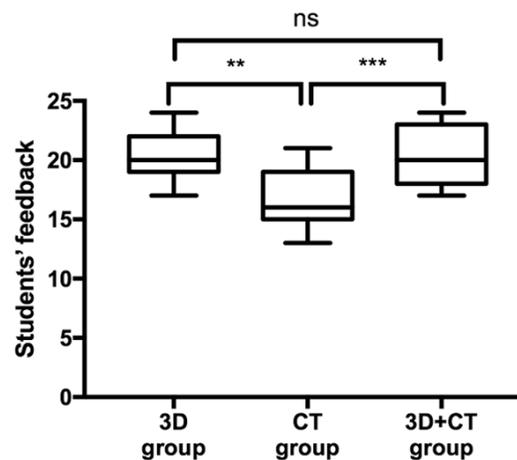


Figure 5. Results of the students' feedback. All students completed a questionnaire about the training section. The satisfaction with the section was significantly better in the groups educated with 3D models compared to in the group educated with CT only ($P < 0.001$).

pre-training test. The 3D models and traditional CT images may have the same validity in anatomical theoretical knowledge education. Similar results were also obtained in Loke and Yammine's research [9, 14].

For further analysis, a third-party assessment was applied in our research to evaluate the training quality. To decrease bias, the surgeons who performed the third-party assessment were unaware of the student groups. The surgeons rated the scores depending on the students' description and comprehension of bladder RC following a review of the patient's clinical data. The results illustrated that 3D models could help improve the students' understanding of the spatial relationship of the bladder and its surrounding structures as well as increase their comprehension of RC processes. The 3D models had significant advantages in understanding the spatial structure of the bladder.

One limitation of this study may have been that the assessment of knowledge acquisition was only reflected by a test that had a limited number of multiple-choice questions [9, 14]. Second, a written test may not reflect the true level of the students' comprehension of the spatial structure of the bladder. Another limitation of the study was that the third-party assessment was dependent on the surgeons'

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experience and their objective evaluation scores.

The advances in 3D printing technology have had a profound effect on medicine, including the areas of surgical planning and navigation, patient education, and surgeon training [1, 5, 8, 13, 15]. The present study demonstrated that the restructuring of 3D physical structures from digital CT data was suitable for 3D printing and that 3D technology is a reliable tool to reveal the anatomical relationship of organs and their surroundings. However, there is still a lack of research on 3D printing technology in bladder cancer, in clinical practices and in patient/trainer education.

Here, we re-created physical 3D bladder models via the Mimics 18.0 system based on computed tomography imaging data. The 3D models captured the essential features of bladder anatomy, including the blood vessels, ureter, and posterior urethra, which were visibly enhanced using coloured resin. During this study, we evaluated the students' satisfaction with the teaching section. The results were similar to those of previous studies in that the physical 3D models were interactive, tangible and useful [2]. The resolution of the CT scan plays a major factor in determining the quality of the physical 3D models; the scans should be in 5 to 3 mm step intervals, and any low-quality images can result in large deviations between the generated physical model and the patient's actual anatomy [3, 10]. However, 3D printing fails to reveal the spatial location of the pelvic plexus because it is difficult to obtain plexus imaging data through a CT scan. While the pelvic plexus is an important anatomical structure in RC bladder surgery, the physical model is sufficient for student education.

It should be noted that although the 3D+CT method did not show significant advancement compared to the 3D-only method in all parameters of student education, the study of CT images is still an important part of medical education for clinical students. The 3D models provided useful tools to assist in the study of CT images, but 3D models cannot replace traditional CT imaging education.

Conclusions

3D models and CT images had the same effect on the students' knowledge acquisition. 3D

models can help improve the students' full understanding of the spatial structures of the bladder and increase their comprehension of RC processes. In addition, physical 3D bladder models can improve student satisfaction with training.

Acknowledgements

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Disclosure of conflict of interest

None.

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