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Computed tomography learning via high-fidelity simulation for undergraduate radiography students

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ABSTRACT

Introduction: Universities offering accredited medical imaging degrees must ensure their graduates can deliver radiographic services including computed tomography (CT). On-campus high-fidelity simulation can potentially facilitate this learning outside the clinical environment yet there is a paucity of research validating its benefits in relation to diagnostic CT.

Methods: A pragmatic multiple methods approach tested for differences in knowledge acquired from two high-fidelity CT simulation environments and explored student perceptions of the learning activities. Third year radiography students (n = 62) were randomly assigned to two groups prior to undertaking a CT placement. Group 1 completed learning activities on a remote-access CT scanner (RA) with peer-assisted learning (PAL). Group 2 completed identical tasks on a local-access CT scanner (LA) facilitated by a CT radiographer. RA students were offered additional scan time if so inclined. Students' CT knowledge was assessed pre- and post-clinical placement. Students were surveyed about their learning experiences. Assessment data was analysed via an ANOVA and survey data via descriptive statistics, t-test and thematic analysis.

Results: Assessment results demonstrated no significant difference in CT knowledge between the groups ($F(1,60) = 0.3$, $p = 0.6$). There was significant improvement in assessment scores between the pre- and post-clinical period for both groups ($F(1,60) = 37.4$, $p < 0.001$). Four themes emerged: remote versus local-access capabilities, facilitation versus PAL, use of a real scanner, and preparedness for the learning activity.

Conclusion: CT knowledge acquisition via RA with PAL is comparable to LA with facilitation. Students reported increased satisfaction and confidence in CT skills via facilitated LA compared to RA students with PAL.

Implications for practice: Opportunity for CT knowledge acquisition is now available outside of the clinical centre via remote-access. PAL requires in-depth training of the peers in technologically rich learning environments.

Introduction

Prior to the inclusion of medical radiation practice within the Australian National Registration and Accreditation Scheme (NRAS) in 2012,[1] the expectations for graduates from medical imaging (radiography) university programs were developed and evaluated by the professional body.[2] Whilst the theory underpinning Computed Tomography (CT) was taught by the university in three-year undergraduate programs that transitioned from the previous system, it was possible to leave practical clinical training in CT for the compulsory work-based professional development year that followed graduation.[3] The situation has now changed where graduates from all accredited university programs are required to deliver CT clinical services without the need for a postgraduate period of supervised practice.[4]

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The creation of cross-sectional 3D imaging generated by CT is a complex process requiring thorough anatomical and spatial awareness along with sound knowledge in, and the implementation of, reconstruction processes and protocols to reduce potentially high-levels of radiation exposure.[5] Over the course of their studies students are required to develop a solid grounding in academic knowledge together with the associated technical and patient-centred capabilities to facilitate a holistic approach to radiography. There is little argument that the clinical environment offers a unique situation for this learning. In Australia, however, there is increasing resource pressure on clinical sites to attend to their core purpose and along with increasing student numbers,[6] the question arises for university educators as to how best to facilitate the development of a range of CT skills in the safety of the on-campus laboratories. In conjunction, for students to develop their patient care skills which is best done in the clinical environment, limiting the distraction of concentrating on technical skill development while on placement is important.[7] To deliver a holistic approach, students not only need to be academically prepared for placement but they also need learning opportunities to develop technical skills outside the clinical learning environment.

Simulation has been well documented to support skill and knowledge acquisition across many areas of healthcare including medicine,[8] dentistry,[9] nursing[10] and allied health.[11–13] Simulation is categorised into low-, medium- and high-fidelity reflecting the level of student participation and realism to the clinical environment.[14] High-fidelity simulation provides a unique platform for students to practise clinical skills in a safe environment without risk to patients.[15] Students are able to self-pace and regulate their learning, reaping the benefits of repeating tasks over and over[16] while hands-on engagement facilitates active learning.[17] In addition, high-fidelity simulation through remote-access and virtual-reality (VR) environments enables access outside the classroom, removing the boundaries imposed by the four-walls of the laboratory environment.[18]

Within the field of radiography, the use of simulation has a long history especially in relation to the development of general radiographic positioning and image critique skills through the use of role play, anthropomorphic phantoms to allow for direct x-ray exposure experiences and computer software programs.[6] However, there is a paucity of research studies validating the benefits of simulation in radiography education. A literature review revealed only three studies assessing the impact of simulated learning on the practical capabilities of radiography students in relation to radiographic positioning and critique, with none of these relating to diagnostic CT.[19–21]

The learner perspective has been more widely investigated within radiography,[22–25] with one of these studies exploring student attitude, confidence and experience towards a CT simulation tool. This study reported mixed levels of student satisfaction when using a remote-access CT scanner as part of their preparation for clinical practice.[25] Findings included recommendations for peer-assisted learning (PAL) or small group facilitated learning to overcome the frustrations reported when interacting with high-fidelity and strongly technologically-driven remote learning as a solo learner. This pilot study provides a foundation for more research into the student CT learning experience accompanied by an investigation of students' practical capabilities when using CT simulation.

With the costs of an onsite CT scanner being prohibitive for most universities, the opportunity for students to actively learn and gain scanning practice has, until now, been limited to the clinical centre. An Australian Commonwealth Government funded remote-access CT scanner (NETRAD CT) administered by the University of Sydney provides an opportunity for high-fidelity simulated learning in diagnostic CT.[26] While remote-access to a real CT scanner facilitates a new kind of learning, it is imperative that the potential impact on student learning is researched to support its resource allocation and implementation.[6] Although studies have found that clinical hours can be reduced with the incorporation of simulation into the health care curricula,[12,27] given the lack of research applicable to diagnostic CT, assessment of the impact of simulation methods within CT is first needed.

The study aimed firstly to assess if there was a difference in knowledge pre- and post-clinical placement for students experiencing different high-fidelity CT simulation learning environments: remote-access (NETRAD CT) with PAL versus a traditional locally-accessed CT scanner with facilitation by a clinically practising academic. The study also undertook to describe the student learning experience.

Methods

Study setting

Monash University offers a four-year Bachelor of Radiography and Medical Imaging (Hons) degree. In semester one of the third year, students complete a CT Methods and Physics unit (subject) which incorporates five weeks of clinical placement, of which at least two weeks are dedicated to CT. Further CT clinical experience is then gained in fourth year. Prior to their third year placement, students attend the University for three weeks of CT pre-clinical preparation. The intervention part of this study was conducted within the pre-clinical weeks as part of the students' preparation for clinical practice in CT. The post-clinical placement assessment was delivered in the week the students returned to Monash University.

Study design

Ethics approval was obtained from the Monash University Human Research Ethics Committee (Project ID 7757) to run a split-cohort study to compare the learning outcomes and experiences of students undertaking high-fidelity CT simulation via either remote- or local-access with either peer- or expert-assisted learning respectively. The comparison of a remote-access CT scanner with PAL to a locally-accessed CT scanner with larger groups but with expert-assistance was selected for two reasons. Firstly, to assess student outcomes between remote-learning and a local hands-on approach and secondly, to investigate if PAL could be used as an alternative to expert-led facilitation. As the intervention was part of the curriculum, both simulation techniques being of high-order afforded both groups equal, although clearly distinct learning opportunities.

Participants

All students enrolled in the third year CT Methods and Physics unit at Monash University in 2018 were invited to participate in the study. Students attended a presentation about the study and the remote-access CT scanner (NETRAD CT) as well as receiving a printed explanatory statement. Students were informed that research participation was voluntary, however, as taking part in a simulation task was part of the assigned curriculum if they did not wish to participate in the study they would still need to complete the learning activity. If students did not wish to participate, their assessment results would not be used in the study data and their academic results would not be impacted. All participants gave written informed consent.

All students (n = 62) elected to participate and completed the study. Students were randomly assigned to two groups: "Remote-access" (RA) (n = 31) or "Local-access" (LA) (n = 31). Each group completed the same coursework and assessment activities, but different teaching approaches were used.

Teaching approach

Each student completed identical scanning tasks and learning activities on head and chest regions of anthropomorphic whole body phantoms covering core CT principles (scan planning, technique factors, and image reconstruction). These two body regions were chosen to represent commonly imaged regions that require different scanning techniques.

Group 1: RA

Students allocated to the RA group completed their scanning tasks using the NETRAD remote-access CT scanner (Toshiba Alexion 16-slice). Through a live video feed, an internet connection and the software program LabShare™, NETRAD CT scans can be repeatedly performed 24 h a day from any location with no radiation risk. Fig. 1 demonstrates the set-up. All students attended a 1 h face-to-face demonstration on how to access the scanner and its basic functions and were also provided with written explanatory guides. Students self-selected into groups of two (with one group of three) and booked a time on the scanner to complete their allocated scanning tasks together for 1.5 h. Students were told in the introductory presentation and the written instructions that they could book additional time on the scanner, however no directive or incentive beyond this was given.

Group 2: LA

Students allocated to the local-access group completed their tasks using a Siemens SOMATOM 16-slice CT Scanner located at a nearby clinical research centre. Students were allocated to small groups (5–6 students) and attended a workshop using the scanner for 1.5 h facilitated by a CT radiographer who was also an academic and one of the researchers in this study. No additional access opportunities were provided.

Data collection and analysis

A pragmatic approach was used which incorporated multiple methods to test for differences in knowledge and to explore student perceptions of the learning activities. Following the completion of the workshops, students undertook equivalent pre- and post-clinical placement assessments via multiple-choice and short-answer knowledge assessment tests on core CT principles (scan planning, technique factors and image reconstruction). Students were surveyed after completing the workshop tasks and the pre-clinical test on their learning experiences using Likert statements and open-ended comments on the best and most difficult aspects of their respective simulation tools. Survey design was based on a recent study into student perceptions of remote-access simulation by some of the same researchers.[25] Each group's questions were the same with just the respective learning activity replaced to represent the groups.

Statistical analyses were undertaken on the pre- and post-clinical placement assessment test results using IBM SPSS Statistics for Windows 24.0 (IBM Corp.: Armonk, NY, USA). An ANOVA including one repeated and one independent factor was used. The number of levels set was two in order to account for the pre- and post-measure. The within subject factor was the pre- and post-clinic time points; the independent factor was membership in either 'remote-access' or 'local-access' groups; the dependent variable was the test scores. Significance level was set at 0.05 and confidence intervals were 95.0%.

The quantitative survey data was analysed with descriptive statistics by reporting the percentages as well as statistical analysis via coding. From the 5-point Likert Scale (Strongly Disagree to Strongly Agree) each response was coded from (−2 to +2 respectively) to produce an overall student value that was ranked against other overall student responses. Negatively geared questions had their code values reversed. From the 14 questions, each overall survey response was coded with a value from −28 to +28. An independent samples t-test was conducted to compare the overall agreement between the two groups ('remote-access' or 'local-access'). To assess any difference in the students' prior CT experience between the groups, a Chi-Square test was performed. Significance levels were set at 0.05.

Thematic analysis was performed on the qualitative student comments using the six-phase process as described by Braun & Clarke.[28] Following familiarisation with the data, a deductive approach was taken with frequency coding used to extract various topics which were then thematically grouped and compiled into a grid matrix as suggested by Miles et al.[29]

Results

Academic

Student assessment results between the remote-access and the local-access groups demonstrated no significant difference in core

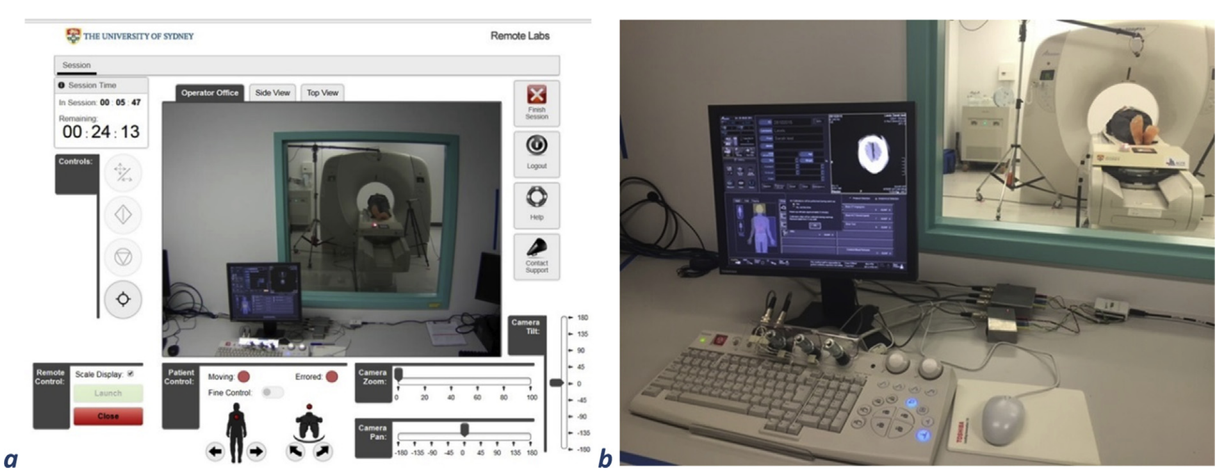

Figure 1. (a, left) Labshare™ screen demonstrating three camera view options and scanner controls via robotic initiation. (b, right) Console room with CT scanner and phantom in the background.

CT knowledge ($F(1,60) = 0.3$, $p = 0.6$). A significant improvement in test scores was demonstrated between the pre- and post-clinical period for both student groups ($F(1,60) = 37.4$, $p < 0.001$).

Student perspective

Quantitative data

30 students from the RA group and 29 students from the LA group completed the surveys (96.8% and 96.7% response rate, respectively). Table 1 represents the participant demographics which demonstrate a majority of students across both groups were female in the age range of 18–22. No significant difference between the number of students who had prior CT experience ($p = 0.367$) was demonstrated.

Statistical analysis of the coded Likert responses demonstrated that students in the LA group were significantly more positive towards their learning activities compared to the students in the RA group (mean ± standard deviation (SD): 13.7 ± 7.0 (LA), 5.6 ± 9.3 (RA); $p < 0.001$) (Table 2). A statement by statement review of the data also demonstrated this, with greater than or equal percentages of agreement (strongly agree and agree combined) observed for the LA compared to the RA group across each statement (Tables 3 and 4).

Qualitative data

Thematic analysis revealed four themes: remote versus local-access capabilities, facilitation versus PAL, use of a 'real' CT scanner, and preparedness for the learning activity.

Remote versus local-access capabilities. Students in the RA group highly valued the remote-access capabilities the NETRAD scanner afforded them, highlighting the benefits of self-paced learning, repeatability and flexibility. Students reported the best aspects to be learning at their own pace without the stress of time constraints and not being rushed. Flexibility was rated highly due to the convenience of after-hours access both in timing and location.

> "*Working at my own pace, not rushed, no stress.*"*(19,RA)*

> "*Being able to learn and understand the controls at my own pace.*"*(10,RA)*

> "*Being able to access it wherever I am.*" *(16,RA)*

> "*Convenience for access at any time.*" *(22,RA)*

Students connected the remote-access with greater time available, allowing them to practise their skills and repeat tasks to consolidate their learning.

> "*… the ability to log on later and practice things I might be unsure about.*" *(2,RA)*

> "*… to be able to repeat [an examination] after making a mistake.*" *(14,RA)*

Conversely comments by the LA group centred on the restrictive nature of a local-access scanner where everything needed to fit into a face-to-face session with no additional access opportunities available due to the inherent supervision requirements.

> "*Very time limited, and could not go back to revisit/redo a scan.*" *(15,LA)*

The time constraints imposed by a scanner that required supervision resulted in limited availability for individual scanning time due to group sizing. Students reported a preference for learning through tactile hands-on experiences.

> "*… as the groups were 5 people we didn't all get to do everything. Would ideally have liked to be able to do a scan on the real machine by myself …*" *(18,LA)*

> "*Remembering what to do is not as easy if you didn't perform the actions yourself.*" *(21,LA)*

Multiple students still found value in the local-access scanner by being physically present. Students assigned value to physically positioning the phantom while gaining familiarity with a CT environment, specifically linking their learning with being physically present.

> "*Being physically present creates a stronger impression when learning.*" *(9,LA)*

Facilitation versus PAL. Facilitation compared with PAL also emerged as a theme. LA students highly valued the contribution of the facilitator through immediate feedback by having their questions answered as they went.

> "*I gained a much better understanding by … being able to get instant feedback from my questions from the facilitator.*" *(7,LA)*

> "*Being able to ask questions about different scanning parameters straight away.*" *(15,LA)*

Conversely, RA students struggled with the lack of guidance that would be provided by a facilitator.

> "*… we needed a bit more guided time using it …*" *(17,RA)*

> "*… very difficult to use at times, unsupervised.*" *(30,RA)*

Positive feedback was still given in relation to working with a peer, however, with students citing the benefits of being able to problem-solve together.

> "*Working in peers was a good thing as it allowed us to problem solve together.*" *(7,RA)*

Table 1
Participant demographics and prior CT experience.

	Remote-access: n (%)	Local-access: n (%)	Chi-squared test
Gender			
Male	7 (23.3)	6 (20.7)	
Female	23 (76.7)	23 (79.3)	
Age group			
18–22	27	27	
23–30	2	0	
30+	1	1	
Prior CT experience			
Yes, in an assisted role	19 (63.3)	15 (51.7)	p = 0.367
No	11 (36.7)	14 (48.3)	

Table 2
Likert coded scores.

	Likert coded score (mean ± SD)	Independent samples t-test
Remote-access	5.6 ± 9.3	p < 0.001
Local-access	13.7 ± 7.0	

Table 3
Remote-access student survey (Likert statements).

Likert statement	Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)
The NETRAD CT helped me to learn the function of the CT's hardware (couch, movement, gantry).	3.3	10.0	30.0	46.7	10.0
I found the NETRAD CT scanner login process and instructions straightforward.	0.0	6.7	30.0	40.0	23.3
I found the NETRAD CT scanner easy to use, and I could do a scout, scan and manage my files.	10.0	33.3	16.7	40.0	0.0
It was easy to appreciate I was using a real scanner, remotely, rather than a simulation scanner.	13.3	20.0	26.7	36.7	3.3
I can see the relevance incorporating the NETRAD CT scanner to the radiography curricula.	3.3	10.0	23.3	60.0	3.3
The learning outcomes of using the NETRAD CT scanner were clear to me.	3.3	13.3	13.3	60.0	0.0
Remote access to the NETRAD CT increased my confidence of CT scanning prior to going on placement.	13.3	20.0	33.3	30.0	3.3
I better understand CT scanning parameters due to access to the NETRAD CT.	13.3	10.0	40.0	33.3	3.3
I have increased understanding of radiation dose in relation to CT scanning through access to the NETRAD CT.	10.0	23.3	56.7	10.0	0.0
The NETRAD CT's ability to repeat CT scans over again has helped my learning.	6.7	10.0	30.0	50.0	3.3
Using NETRAD CT with a peer improved my general CT knowledge as I could share and gain knowledge.	6.7	6.7	6.7	53.3	26.7
There is no benefit to using NETRAD CT with a peer.	36.7	53.3	6.7	3.3	0.0
Operating NETRAD CT with a peer increased my confidence in using remote-access simulation.	10.0	0.0	13.3	63.3	13.3
Using NETRAD CT with a peer increased my enjoyment of using a remote-access scanner.	3.3	3.3	23.3	46.7	23.3

Table 4
Local-access student survey (Likert statements).

Likert statement	Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)
The CT Workshop helped me to learn the function of the CT's hardware (couch, movement, gantry).	3.5	0.0	20.7	58.6	17.2
I found the CT Workshop's instructions straightforward.	0.0	3.5	20.7	58.6	17.2
I found the CT Workshop scanner easy to use, and I could do a scout, scan and manage the data files.	0.0	13.8	44.8	37.9	3.5
Being present with a real scanner was more beneficial than a remote-access or simulation one.	3.5	0.0	24.1	24.1	48.3
I can see the relevance of incorporating time on a CT Scanner into the radiography curricula.	0.0	0.0	0.0	48.3	51.7
The learning outcomes of using the CT Scanner were clear to me.	0.0	3.5	20.7	58.6	17.2
Completing the CT Workshop increased my confidence of CT scanning prior to going on placement.	0.0	10.3	31.0	37.9	20.7
I better understand CT scanning parameters due to access to the CT Workshop scanner.	3.5	6.9	17.2	55.2	17.2
I have increased understanding of radiation dose in relation to CT scanning through access to the CT Workshop scanner.	3.5	17.2	20.7	48.3	10.3
I would have benefited from being able to access the CT scanner (at MBI) after the workshop to repeat CT scans over again.	0.0	0.0	13.8	41.4	44.8
Using the CT Scanner with a facilitator improved my general CT knowledge as I could ask my questions and gain knowledge.	0.0	0.0	3.5	44.8	51.7
There is no benefit to a CT Workshop with a facilitator.	51.7	34.5	10.3	3.5	0.0
Operating the CT Scanner with a facilitator increased my confidence in using a CT Scanner.	0.0	3.5	17.2	51.7	27.6
Using the CT Scanner with a facilitator increased my enjoyment of using a CT Scanner.	0.0	3.5	17.2	51.7	27.6

Use of a 'real' CT scanner. Both groups perceived that confidence was gained and overall understanding improved by performing examinations on an actual CT scanner. Conflicting responses, however, were noted in the RA group. Some students felt that they still hadn't used a 'real' CT scanner due to the remote set-up.

> "*Being able to experience what it was like using a CT scanner as it allowed me to feel more prepared for placement.*" (4,LA)

> "*I liked being able to practise on a real machine even though it was remotely [accessed] …*" (17,RA)

> "*Still don't feel too confident when going to placement for CT as I still haven't used a real CT scanner in real life such as moving the patient table via the physical buttons.*" (29,RA)

Preparedness for the learning activity. Both groups commented on the overall challenge of the task based on their lack of familiarity with a CT scanner, finding it time-consuming and difficult to navigate their way around an unfamiliar console.

> "*It was difficult finding where things were on the console purely because I have never used a CT scanner before*" (4,LA)

"*Navigating the user interface was the most difficult. Even with a facilitator assisting us, it can be frustrating if you are completely unfamiliar with the layout.*" *(9,LA)*

"*The NETRAD system was very difficult to actually operate … If the NETRAD was easier to operate then it will actually be a really helpful resource.*" *(26,RA)*

Discussion

High-fidelity simulation provides opportunities for improvement in transition from academic studies to the clinical environment.[14] With competence in CT now a requirement for radiography graduates,[4] the implementation and validation of CT simulation tools is essential.[6] This study investigated the differences in CT knowledge in two different high-fidelity learning environments and explored the student learning experience. Results demonstrate that both remote and hands-on CT simulation afford equal learning opportunities, however student preference is for facilitated tactile learning with a CT radiographer.

Remote-access simulation provided the students with flexibility and ownership of their learning. Students valued being able to learn at their own pace without the stress of time constraints and the freedom for students to create their own learning pathways in this environment has been shown to improve long-term retention of skills compared to instructor-regulated learning only.[30,31] The additional NETRAD CT access, if utilised, afforded the students more opportunity for learning through repetition, a key part of skill acquisition and mastery.[16] Students recognised the benefits of being able to practise their skills in a safe environment without risk to the patient.[15] In alignment with this, students in the local-access setting described the challenges of time restriction and larger group sizes which resulted in decreased participation. Students themselves articulated the benefits of continual active learning, citing memory improvement when performing tasks themselves, which is supported by the literature.[17] With this in mind, the significance of being physically present was not lost on the students, with LA participants highly valuing the immersive nature of being in a CT environment; positioning the 'patient' with their own hands and physically experiencing using a CT scanner gave support to the importance of tactile hands-on learning. Although both CT tools were commercial grade CT scanners, RA students reported the challenges of being able to appreciate that the scanner was real given they weren't physically present and as such reported loss of confidence in preparedness for clinical placement. This is a key finding, given confidence in skill development in medical and health education is recognised as a necessary quality of healthcare workers[32] while a lack of confidence can hinder students' ability to acquire new information.[33] The challenges associated with students not perceiving simulated environments as the 'real thing' is not a new finding and has previously been acknowledged.[20,25,34]

Further to the physical differences between the two learning opportunities, the role of the facilitator compared with the peer was also found to have influenced the students' experience. Students found guidance and instant feedback from the facilitator helped with their understanding and confidence, whereas the challenges faced when using a relatively unfamiliar RA technological system appear to have outweighed the benefits of PAL in the students' eyes. With the barriers of hierarchy in traditional learning environments removed, PAL can provide a safe place for students to explore and learn in a stress-reduced environment[35,36] with the development of higher-order cognitive skills fostered through the process of teaching one another.[30] However, for a successful intervention to occur, adequate preparation of the peers is essential.[37] As CT knowledge was at a novice level for all students, it is possible that a peer–peer scenario for RA students was not ideal when combined with complex interactions with two interfaces (Lab Share and Toshiba CT console).

In this study, although both groups demonstrated equivalent academic learning, there was significant difference in the students' overall satisfaction between LA and RA along with their own perceived confidence in CT skills and perceived understanding of core CT concepts. Analysis of the qualitative responses suggests the closing of the feedback loop provided by the expert facilitator engendered validation of learning in a way that the PAL RA scenario could not. Facilitator-led students were able to receive "instant feedback" (7,LA) and "ask questions … straightaway" (15,LA) which provided the students with affirmation and identification of areas for improvement, both essential elements of the feedback process in simulation.[38] It is therefore recognised that although PAL has value, a greater degree of separation between the peers could provide the required support for a new and technologically rich simulation environment.[37,39] A possible strategy is to pair 4th year students with 3rd year students for future PAL RA learning teams.

The benefits of clinical placement were strongly highlighted in the test scores. Following clinical placement, both groups demonstrated significant improvement in their core CT knowledge. In many ways it is unsurprising that dedicated time in a clinical environment brought improvement to both groups and supports the continued use of an integrated approach of clinical and academic learning.[6]

Limitations

Students sat equivalent pre- and post-clinical assessments and hence their ability to prepare for the post-clinical assessment may have been enhanced, given sensitisation to the types or number of questions included can affect scores of subsequent tests in a pre- and post-assessment setting.[40] Another potential limitation is that the post-clinical test scores were summative, adding to the students' final grade; whereas the pre-clinical test scores were formative, whereby students only needed to attain a pass grade in order to demonstrate sufficient knowledge to attend clinical placement. The phenomenon that students pay most attention to what is being assessed and graded[41,42] may therefore have impacted these elevated CT knowledge results. Students talking about their different learning experiences between the groups cannot be ruled out as a potential limitation to the students' assessment result data given the time between the intervention and assessments. This contamination effect is a known challenge in health profession education.[43,44]

It is acknowledged that student learning was not restricted to a 1.5 h workshop alone. Additional learning resources were available from which both groups could have benefited. However, given that both groups had equal access to the additional resources, it is presumed that differences seen in the results likely correlate with the intervention. The variance in CT experiences of students on clinical placement cannot be ruled out as a bias to the results.

Future directions

While this study investigated the impact on core knowledge acquisition, future study should evaluate the impact of remote-access CT simulation on student clinical performance, in particular in relation to their scanning skills. Use of an Objective

Structured Clinical Exam (OSCE) or an analysis of the students' clinical skills assessments could demonstrate the impact of simulation on technical and practical scanning capabilities. The potential for near-peer learning in place of peer–peer learning to enhance students' confidence in using a technological rich simulation tool could be explored.

Conclusion

High-fidelity simulation via RA with PAL has a similar impact on learning core CT knowledge compared to simulation in a local, tactile environment facilitated by a CT Radiographer. Student satisfaction and confidence in CT skills was higher in a facilitated LA environment, highlighting the need for more preparation and/or peer development in a remote-access setting. This study suggests that opportunities for skill acquisition and knowledge consolidation in institutions without access to a CT scanner on-site are now available remotely with no loss of learning. Future evaluation seeks to determine the effectiveness of CT simulation on practical student scanning skills and clinical performance.

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Conflict of interest statement

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