2008

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Abstract: This paper reports on a research project conducted at the Advanced Clinical Skills Centre, University of Auckland, to determine whether the provision of a carefully engineered integrated virtual reality simulator for male and female urinary catheter insertion would increase student confidence levels and competency for those two skills. We present a literature review that demonstrates the increasing importance of simulation in medical education whilst detailing the perceived benefits and drawbacks of using simulations in medical education. We then present our research methodology including student numbers, procedures followed during the research, forms of evaluation carried out during the research and the current research stage. We conclude with the difficulties encountered in our study and a statement concerning the current status of our research.

Research Background

The Advanced Clinical Skills Centre at the University of Auckland offers courses at all levels in clinical procedures including: Advanced Cardiac Life Support (ACLS), crisis management in anaesthesia, open and laparoscopic surgery, general surgery, gynaecology, orthopaedics, general practice, theatre nursing and other disciplines. Modern methods used in an attempt to foster improved skill acquisition in the area of medical education include the provision of video material, multimedia presentations and use of post training course simulations (Issenberg et al., 2007). Simulation is becoming increasingly recognized as a method for training and assessment (Issenberg et al., 2007; Jones, 2002b; Moorthy, Munz, Sarker, & Darzi, 2003) with one author suggesting that simulations are now used routinely in simulation centers around the world (Epstein, 2007). Good suggests that over one third of all medical schools in the USA make use of human patient simulators with hundreds more patient simulators in use at universities, colleges and medical centers world wide (Good, 2003). A world wide survey in 2004 identified 158 medical education simulation centers with a significant number involved in undergraduate teaching (Weller, 2004). Through collaboration with Go Virtual Medical – www.govirtualmedical.com – an Auckland based company that has produced a suite of simulations for training in procedural skills, the Advanced Clinical Skills Centre had the opportunity to trial the use of the Integrated Simulator for two clinical skills procedures: male and female urinary catheterization.

We conducted research around the trial of the integrated simulator the purpose of which was to determine whether the introduction of a carefully engineered integrated virtual reality simulator for the clinical skills of male and female catheter insertion would increase student confidence levels and enhance skill acquisition and skill retention (i.e. competence). It was important to measure both confidence and competence because confidence is not a reliable indicator of competence. For example, as a result of previous exposure to particular procedures during clinical practice students may feel confident about their ability in certain skills whilst performing poorly when assessed in those skills (P. J. Morgan & Cleave-Hogg, 2002a).

An initial review of the literature provided us with the widely accepted three stage theory of motor skill acquisition (Reznick & MacRae, 2007) which suggests that there are three stages to skill acquisition: a cognitive stage during which the learner intellectualizes the task; an integrative stage consisting of practice and feedback during which the conceptual knowledge is translated into appropriate motor behaviour; and an autonomous stage in which continued practice has led to “automatic” performance. Given the perceived learning benefits of deliberate practice (Good, 2003; Park et al., 2007) together with immediate feedback for skill acquisition (Issenberg, Gordon, Gordon, Safford, & Hart, 2001; Issenberg et al., 2007; Kneebone, 2003; Maran & Glavin, 2003; Reznick & MacRae, 2007) the hypothesis that repeated use of a simulator for male and female catheter insertion would lead to increased student confidence and improved competency seemed to be a reasonable one.

The literature review showed that there is evidence that medical students value the chance to work with simulators (Good, 2003; P. J. Morgan & Cleave-Hogg, 2002a; Weller, 2004). However, whilst there are studies that would support claims concerning the “efficacy” of screen-based and realistic stimulators for skill enhancement (Park et al., 2007; Ziv, Wolpe, Small, & Glick, 2003), human patient simulators (Good, 2003; Pamela J. Morgan, Cleave-Hogg, Mcllroy, & Devitt, 2002b) and virtual reality simulation (Colt, Crawford, & Galbraith, 2001), a number of authors – including those who cite limited positive results for the use of simulations – note the need for further research into the use of simulations in order to determine benefits for student learning (Gaba, 2004; Kneebone, 2003; Reznick & MacRae, 2007; Weller, 2004; Ziv et al., 2003).

Simulations

Definitions and Categorizations

There are various definitions of simulation all of which have in common the concept of representation or replication of some aspect of reality (Jones, 2002b; Kneebone, 2003; Ziv, Small, & Wolpe, 2000). Gaba writes that within healthcare the term simulation usually refers to “a device that presents a simulated patient (or part of a patient) and interacts appropriately with the actions taken by the simulation participant”(Gaba, 2004, p.2). There is clearly a focus in current medical education on the potential value of a variety of “device” type patient simulators (Gaba, 2004; Issenberg et al., 2001; Kneebone, 2003). However Ziv's five type categorisation of simulators based upon “mode” of delivery makes it clear that the simulated patient is only one type of simulation in use in medical education. Ziv divides simulators into five types (Ziv et al., 2003): low tech simulators such as models or mannequins; simulated or standardized patients such as actors playing a role; screen-based computer simulators such as problem based learning; complex task trainers of the virtual reality type used in this study; and realistic patient simulators. Realistic patient simulators – perceived to offer the advantage of emotional involvement for the student thus leading to deeper cognitive processing (Friedrich, 2007) – can be categorized as either advanced human patient simulators (AHPS) (Jones, 2002b) or medium fidelity patient simulators (Weller, 2004) with the difference between the two being defined in terms of the relative complexity of the simulation environment (Good, 2003).Virtual Reality (VR) which “completely integrates the user into the world of the computer” (Vozenilek, Huff, Reznek, & Gordon, 2004, p.1151) is an immersive form of simulation that has been used successfully for training purposes in other industries such as aviation, business, the nuclear power industry and the military for number of years (Issenberg et al., 2007; Vozenilek et al., 2004; Ziv et al., 2000)(Issenberg et al., 2007, p.861) with increasing recognition being given to the value of this form of simulation for medical education (Vozenilek et al., 2004).

The Go Virtual medical simulations used in this study were developed over a 3 year period by a team of clinicians, 3D animators, and computer programmers. In the case of the Go Virtual medical simulations we refer to a 'cognitive simulator' because the simulations are not fully interactive. In terms of interaction, if the right decisions are made the clinical procedure can be undertaken. Clicking on the right portion of anatomy with the right instrument in the correct hand at the right time will result in playing a pre-rendered sequence and allow progress to the next step of the procedure. The software runs on a gaming engine called UMAJIN, which is based upon a hybrid programming language that incorporates elements of C++, C sharp, and visual basic. The engine was developed by Unlimited Realities Ltd and adjusted to suit the needs of the Go Virtual Medical integrated simulator. Clinical content for each module was carefully researched by a team of clinicians and reproduced in a specific format. A filming team captured a video of the relevant procedure which was then edited, voiced over, and handed to the animators. The animation team then created the relevant 3D anatomy images and 3D movie sequences for the simulations. Finally, all the content was incorporated into the Go Virtual Medical interface by the programming team. The clinical content, the imagery, and the software functionality were all reviewed and tested at several stages. The Go Virtual Medical integrated simulator interface offers comprehensive learning of a range of practical procedures in the form of electronic text, 3D anatomy, video, and a 3D simulator which is operated by two mice in lieu of expensive, sophisticated hardware. A logbook displays the user's performance on the simulations. Hence, the reader can read, see, practice, and repeat a selected procedure, and receive feedback on performance. The two mouse approach does not offer tactile or haptic feedback; rather the integrated simulator is a *cognitive* trainer.

Benefits and Drawbacks

Whilst we had a core hypothesis for our research we also wanted to review the literature to identify a range of perceived benefits and drawbacks to the use of simulations in medical education and to consider whether there were any issues with the use of simulation that we had not yet taken into consideration. We categorized the benefits of simulations into three distinct types: meeting individual learner needs; increasing practice opportunities; and ensuring appropriate assessment.

With reference to human patient simulators Weller writes that, “Simulation offers students a unique opportunity to learn through experience, aided by reflection and feedback and the opportunity to practice. Simulation training is highly engaging, interactive and clearly relevant to practice. Students learn from each other in a safe, non threatening environment. These attributes of simulation-based education are consistent with models of effective educational interventions" (Weller, 2004, p.38) Also with reference to human patient simulators Jones notes that the human patient simulator provides students with the opportunity to engage in problem based learning – the problem being an “adverse patient condition or illness” and that “direct involvement” or learning by doing provides “optimal educational impact” for the students because it is through experience that new skills are learned (Jones, 2002a, 2002b). Reznick also recognizes the educational value of problem based learning and of learning by doing whilst noting additionally that simulations meet the educational needs of residents as self-directed adult learners (Reznick, 1993). Meeting the particular needs of learners is a benefit noted by Ziv who writes that simulations allow students to study at their own pace whilst repeating procedures as required to increase their level of confidence and proficiency (Ziv et al., 2003).

The use of simulations provides for the opportunity to overcome the limitations of “the apprentice method of learning from actual clinical encounters [which] were constrained in a number of ways" (Ziv et al., 2000, p.493). For example, whilst training has traditionally involved patients, simulations provide the opportunity for training in procedures that do not occur sufficiently frequently in “real life” to allow students to gain the requisite skills (Vozenilek et al., 2004). Simulations also allow for training determined by learner rather than patient needs. For example, in a simulated environment a learner can focus on an entire procedure or particular parts of a procedure practising as often as necessary. This would simply not be feasible with real patients (Good, 2003). Finally, there is an ethical imperative in medicine to do no harm that conflicts with the fact that trainees have to practice their skills on live patients (Ziv et al., 2003, p.783). Simulations provide students with a safe environment in which to practice their skills (Weller, 2004) thereby minimising risk to patients and improving patient safety (Park et al., 2007; Ziv et al., 2003).

Feasible, valid and reliable technical skills assessment is of crucial importance both for training per se and to ensure high quality surgical care whilst reducing the possibility of potential errors that might result from poor performance (Moorthy et al., 2003). Although multiple forms of training and assessment exist within the medical profession (Epstein, 2007) specific training in particular clinical skills is particularly important in terms of determining procedural competency especially in a busy clinical setting in which oversight on part of busy physicians with multiple demands on their time is a distinct possibility (Lammers, Temple, Wagner, & Ray, 2005). Furthermore, it is important that the training and assessment methods be free of the subjectivity associated with the type of broad perspective ratings provided by physicians at the end of a clinical round (Epstein, 2007). Simulations – particularly when delivered in conjunction with face to face training – can help to address assessment issues by providing "objective evidence of performance whilst also providing immediate feedback" (Good, 2003, p.18) thereby offering the potential to improve performance assessment (Ziv et al., 2000).

A number of potential drawbacks have been recognized with the use of simulations. Good notes a lack of realism with simulators – for example, the skin color of patient simulator not changing appropriately for a particular medical condition – but he also recognizes that the realism of simulators is constantly improving (Good, 2003). The cost of simulators is perceived to be relatively high although this obviously depends upon the type of simulator. Concerns about cost are common (Gaba, 2004; Park et al., 2007). Maintenance and upgrade issues are also a concern. For example, if a medical procedure were to change then a virtual reality environment teaching that skill would have to be upgraded. This concern is again contingent on the type of simulator under consideration. Isenberg's final concern has to do with the practical difficulties – staff time and commitment – of integrating simulations into the curriculum (Issenberg et al., 2007). The potential benefits of simulated training need to be realized through faculty learning to "hone new instructional skills and techniques" (Good, 2003, p.20). This requires a commitment of time and a considerable degree of effort on the part of faculty.

The Simulation Study

Study population

The study population consisted of 22 final year medical students from the University of Auckland Medical School. Students were all (trainee interns, or TIs), divided into 2 groups. Group 1 (n=12) were the control group. Group 2 (n=10) were the intervention group. All students were enrolled in a clinical skills course that lasted two days. The clinical skills taught during the two days included ACLS, lumbar puncture procedure, nasogastric tube (NGT) insertion, urinary catheterization of a male and female patient, and the care of an open contaminated wound. All TIs are required to complete the clinical skills course in their final year. Six clinical skills courses are held throughout the year and this study population was randomly selected from the six cycles of TIs.

Pre-Course Evaluation

Carrying out a randomized controlled trial in medical education has been deemed to be difficult for three main reasons (Prideaux, 2002): the feasibility and justifiability of carrying out a randomized trial, particularly if the use of a control group is perceived to disadvantage some students (Pamela J. Morgan et al., 2002b); control of the variables; and the choice of appropriate outcome measures. Our own study was conceived and carried out with these points firmly in mind and we believe we addressed these issues appropriately.

Both groups were provided with a pre-course evaluation to measure their previous exposure to the urinary catheter insertion process. The purpose of the pre-course evaluation was to determine levels of extant knowledge that might have confounded the results of the study (Lammers et al., 2005). The participants were assured that their responses to the questionnaire would remain confidential. The pre-course questionnaire consisted of five questions: (a) Prior exposure to the male and female urinary catheterization skill, (b) Their self-reported level of confidence performing the skills, (c) The importance of mastering the procedures for male and female urinary catheterizations, (d) To what extent trainees thought they would make use of the clinical procedure in future medical practice, and (e) Trainees level of fatigue prior to receiving training for these procedures. Participants were also asked to state in their own words what they expected to learn from the clinical skills course and to provide any other comments.

Procedure

Directly following the pre-course questionnaire, the participants viewed a 15-minute male urinary catheter insertion video presentation and a 15-minute female urinary catheter insertion video. Participants also watched a live 10 minute demonstration of the male and female urinary catheterization skill (5 minutes for each skill) performed on a mannequin by a physician in the clinical skills centre. The total training time was 40 minutes. The students were then given the opportunity to practice each skill on the male and female mannequins in the Advanced Clinical Skills Centre. Each student was allowed to have one practice attempt for both the male and female catheterisation procedure under supervision of the clinical tutors. All students participated in the practice session. Each practice procedure lasted on average 10 minutes. The students then proceeded directly to complete both procedures whilst being assessed by a physician registered as a general practitioner.

Kneebone recognises that there "is as yet no uniform approach to measuring performance" (Kneebone, 2003, p.273). However, whilst student competency in particular surgical procedures can be assessed using both a checklist and a global rating scale (Martin et al., 1997) – where the global rating scale consists of procedural components that are assessed in terms of a five point Likert scale (Moorthy et al., 2003) – it was decided that the male and female urinary catheterization procedures for this study were not sufficiently complex to warrant the use of a global rating scale. Therefore, the assessment tool consisted of checklist compiled by a physician – direct observation with criteria – for the steps in the procedures. Reliability and validity for this form of assessment has been shown to be high for surgical skills procedures since subjectivity is removed from the evaluation process (Moorthy et al., 2003).

Skills may be defined as, "actions and reactions which an individual performs in a competent way to achieve a goal" (Issenberg et al., 2001, p.21). A student may have no skill, some skill or complete skills and it is therefore important to define the level of acceptable mastery. In this study 'some skill' was considered to be acceptable and each participant had to be able to satisfactorily insert a catheter into the male and female simulation models, measured against a set of metrics (e.g. communication with patient, correct tray setup [i.e., no need to interrupt flow of procedure due to inadequate tray setup], no breach of sterility, etc.).The intervention group was given unlimited access to the integrated simulator directly following their clinical skills assessment and the control group did not receive any intervention.

After the initial evaluation participants were randomly assigned to two groups: simulation and control. The randomization process involved consecutively numbering 22 envelopes with a group allocation to either the intervention group (simulation) or control group in each envelope. The participants were irreversibly randomized by opening their own sealed envelopes after consenting to participate in the study. The intervention group was given unlimited access to the integrated simulator in the form of a CD ROM (the integrated simulator software can be installed on any PC hard drive). Use of the simulation software was explained to the intervention group and members of the intervention group were contacted via email one week after issuing the software to inquire if they were experiencing any difficulties using the software. In order to avoid a confounding variable the control group was not given any form of software or technology to support their learning. The intervention group was asked not to share the simulation with their peers.

After 3 months, all participants were re-tested against the same set of metrics and by the same evaluators used in the training course, to ascertain competency (primary end point). Evaluators were not aware of which group of students they were assessing. Students filled out a 3 month follow up questionnaire that measured exposure to each of the procedures since attending the initial skills course and confidence levels for each procedure (secondary endpoint). At the time of writing, the 3-month re-test has occurred and the evaluations are currently with a statistician for analysis.

Discussion

We encountered difficulties with the follow up evaluation in terms of participant attendance. The member of staff responsible for running the study spent a considerable amount of time and effort contacting students to ensure their participation. Eventually a second evaluation evening was run in order to accommodate all students. Kneebone recognizes the difficulty of evaluating the educational benefits of simulations including small samples sizes and logistical problems with carrying out studies (Kneebone, 2003). The sample size for our study was relatively small because of the logistical issues – student participation, availability of demonstrators and examiners – of organising and running the evaluations. We are aware of the need to run further studies and to look at the research methodology particularly in terms of other contributing variables. Ideally we would also look at the transfer of skills to live patients because ultimately the value of the simulations for educational purposes needs to be validated in terms of transference of the skills learned to the clinical setting. (Park et al., 2007).

At the time of writing the data from the study is being analysed by a statistician and we expect results to be available December 2007.

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