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Simulation- and Web-Based Learning of Intravenous Pharmacotherapy: A 2-Group Comparison With 6 Months' Follow-Up

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A B S T R A C T

Introduction: Health care providers can make errors when administering medicines, and when medicines are given intravenously (IV) or are high-alert medicines (e.g., contrast agents, analgesics, adrenergic agonists). Errors can result in significant patient harm. Radiology departments' professionals' medication competence should be developed and regularly evaluated using effective evidence-based learning methods. This quasi-experimental study aimed to compare IV pharmacotherapy knowledge acquisition and retention after simulation-based learning or web-based learning.
Methods: Radiographers were recruited from two hospitals' clinical radiology units (experimental group, $n = 36$; control group, $n = 41$). The participants completed the same knowledge test related to IV pharmacotherapy three times: (1) before educational interventions (pretest); (2) post-test 1 to 2 weeks after the interventions; and (3) follow-up 6 months later to evaluate the sustainability of learning.
Results: Both simulation-based and web-based learning increased radiographers' knowledge of IV pharmacotherapeutics. In sensitivity analysis (groups matched for IV pharmacotherapeutics knowledge at baseline), scores in the simulation arm showed greater increase, but the difference did not reach statistical significance. The changes were sustained at 6 months. Furthermore, 82% (18 of 22) in the simulation arm had enhanced scores at post-test compared with 68% (23 of 34) in web-based arm and 62% (18 of 29) in the matched arm.
Discussion: The improvement in knowledge of IV pharmacotherapy was greater after simulation-based learning, and these improvements were sustained 6 months later. However, the impact of enhanced knowledge on the processes and outcomes of care require further exploration.

Introduction

Approximately 1 in 10 adult inpatients suffers an adverse drug event (ADE), either a harmful error or an adverse drug reaction (Bouvy, De Bruin, & Koopmanschap, 2015; Martins, Giordani, & Rozenfeld, 2014). Prevalence is estimated at 9.2% (interquartile range, 4.6–12.4%), with little international variation (de Vries, Ramrattan, Smorenburg, Gouma, & Boermeester, 2008; Martins et al., 2014). Estimates of ADEs vary as reporting methods are not standardized (Martins et al., 2014). Observational studies among hospital inpatients indicate a prevalence of 10.1% to 11.0% (with wide variation, 5.8–46.3%) (Alhawassi, Krass, Bajorek, & Pont, 2014; Bouvy et al., 2015), but case finding retrospective reviews give higher prevalence (27% [125 of 463] patients) (Harkanen et al., 2015). Administration of intravenous (IV) medicines is more

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vulnerable to error than other routes, with errors occurring in 50% to 70% of doses administered (Keers, Williams, Cooke, & Ashcroft, 2013b; Westbrook, Rob, Woods, & Parry, 2011). At present, IV medicines, such as injections of contrast media, analgesics, and sedatives, are increasingly used during routine radiographic imaging, image-guided procedures, and interventional radiology (Miller, Price, & Vosper, 2011; Niell et al., 2015): any errors with these medicines are likely to cause significant harm (Institute for Safe Medication Practices, 2016).

Human factors (e.g., inadequate medication competence, particularly poor theoretical knowledge) are associated with increased likelihood of medication errors (Keers, Williams, Cooke, & Ashcroft, 2015; Simonsen, Johansson, Daehlin, Osvik, & Farup, 2011). Therefore, a sound theoretical medication competence is crucial for every health care professional dealing with medication, providing base for practical- and decision-making competencies to ensure patient safety (Sulosaari, Suhonen, & Leino-Kilpi, 2011).

Many educational interventions have been developed to enhance medication competence, but their effectiveness is variable (Berdot et al., 2016; Harkanen, Voutilainen, Turunen, & Vehvilainen-Julkunen, 2016). For example, web-based learning (computer-assisted learning, e-learning, online learning, and Internet-based learning) is suggested as an effective learning method for safe medication management (Lee & Lin, 2013; Mettiainen, Luojus, Salminen, & Koivula., 2014) and is used widely in health care professionals' education (Cook, Graside, Levinson, Dupras, & Montori, 2010b; Pinto et al., 2008). Web-based learning allows independence of place and time, is information rich and interactive, and may reduce learning time (Koch, 2014); on the other hand, the time taken seems to be correlated with knowledge outcomes, that is, effective learning takes time (Cook, Levinson, & Garside, 2010a). Disadvantages of web-based learning include poor interaction and communication and failure to account for learners' individual needs and circumstances (Cook et al., 2010b; Koch, 2014; Wong, Greenhalgh, & Pawson, 2010). Web-based learning interventions are as effective as traditional teaching and more effective than no educational intervention (Cook et al., 2008; Du et al., 2013; McCutcheon, Lohan, Traynor, & Martin, 2015).

Simulation-based learning has gained popularity in recent years. Simulations include a variety of technologies from computer programs to standardized patients and full-scale scenarios with imitation of real-world patient care (Curtis, Diazgranados, & Feldman, 2012). Simulations can be implemented in separate simulation centers or real clinical environments (in situ simulations) with real equipment and the same teams as in actual patient care (Couto, Kerrey, Taylor, FitzGerald, & Geis, 2015; Rosen, Hunt, Pronovost, Federowicz, & Weaver, 2012). Simulations can be used in competency assessment (Hagler & Wilson, 2013) or learning tools. Several learning outcomes have been reported, such as enhanced knowledge, clinical skills, and teamwork (Aura, Sormunen, Jordan, Tossavainen, & Turunen, 2015; Curran et al., 2015; Niell et al., 2015; Tofil et al., 2010). Proponents feel that simulations facilitate application of theory to clinical practice (Jansson et al., 2014; Wang et al., 2011) and support patient safety learning (Aura et al., 2015; Shearer, 2013). Reviews and meta-analyses indicate moderate or large effects when compared with no intervention (Cook et al., 2011; Dilaveri, Szostek, Wang, & Cook, 2013; Mundell, Kennedy, Szostek, & Cook, 2013) but small or statistically insignificant effects when compared with other interventions (Cook et al., 2012; Ilgen, Sherbino, & Cook, 2013). Simulations, particularly those using advanced technology, are costly, and appropriate training and education to faculty and administrative support entail additional expenditure (Al-Ghareeb & Cooper, 2015; Cook et al., 2012).

To our knowledge, there are few studies of simulation-based learning in radiology departments or involving radiographers (Aura, Jordan, Saano, Tossavainen, & Turunen, 2016; Niell et al., 2015). The evidence for use in pharmacotherapy education remains limited (Aura et al., 2015), and reports on knowledge retention are inconclusive (Rutherford-Hemming et al., 2016). Deficit in theoretical medication competence is a recognized cause of medication errors (Keers, Williams, Cooke, & Ashcroft, 2013a; Reason, 2001) and thus a threat to patient safety. Therefore, every effort should be made to determine the optimum strategies for teaching and learning pharmacotherapeutics.

We aimed to explore whether the acquisition of knowledge of IV pharmacotherapy short-term (1–2 weeks later) and long-term (6 months postintervention) results differed between experimental (simulation-based learning) and control (web-based learning) groups in this quasi-experimental study.

Methods

Instrument Development

A knowledge test *Learning Intravenous Medication Management* (LIMM) was developed as a teacher-constructed learning achievement test (Johnson & Christensen, 2012) in a multiprofessional team. The team consisted of two clinical teachers of nursing, one anesthesiologist, and one nurse manager. It included statements on patient safety (four items and/or statements), anaphylaxis (seven items), opioids (eight items), sedatives (six items), atropine (three items), and etilefrine hydrochloride (a sympathomimetic drug, two items). The items were evidence based and constructed from the objectives and content of the course (Oermann & Gaberson, 2009). The test was composed as a true-false test with 30 statements (correct scored as one point and incorrect or no answer as zero points). The LIMM test is presented in Appendix 1 (see Supplemental Data).

Content Validity

The test was evaluated for content validity by an expert panel of five members (Polit, Beck, & Owen, 2007); a radiologist, an anesthesiologist, a pharmacist, a radiographer, and a radiography teacher. They were asked to rate each item for clarity and relevancy relating to objectives in a three-point scale (1 = not clear and/or relevant, 2 = somewhat clear and/or relevant, and 3 = clear and/or relevant) and provide comments for items rated as one or two. To calculate the item-level content validity index (I-CVI), the number of experts rating three was divided by the total number of experts, that is, proportion of agreement was counted (Polit et al., 2007); see Appendix 1. The content validity index for the whole scale was calculated as the mean score (I-CVI) across all items (scale-level content validity index, averaging calculation method [S-CVI/Ave]) (Polit et al., 2007).

The S-CVI/Ave was 0.9, indicating excellent content validity (DeVon et al., 2007; Polit et al., 2007). From all 30 items in the test, 27 had I-CVIs of 0.8 to 1.0 indicating excellent content validity (Appendix 1); three items had I-CVI of 0.6, and these were reviewed and adjusted in the light of experts' qualitative feedback (Polit et al., 2007).

Face Validity

To assess face validity of the IV pharmacotherapy knowledge test, a pilot study was conducted to examine the clarity and intelligibility of items and also to examine the estimated time for answering the test (DeVon et al., 2007; Rattray & Jones, 2007). A group ($N = 15$) of final semester radiotherapy students, who were