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Preparation of Simulation Programs regarding Excess-dose Drug Administration and Acute-phase Condition Changes and Its Evaluation by Students

Jin TOKUNAGA,* Norito TAKAMURA, Kenji OGATA, Nao SETOGUCHI, Toshikazu MATSUOKA, and Keizo SATO

School of Pharmaceutical Sciences, Kyushu University of Health and Welfare, 1714–1 Yoshino-machi, Nobeoka, Miyazaki 882–8508, Japan

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Vital-sign checks and physical assessment have been performed by physicians and nurses among medical staff in particular. However, pharmacists must also have basic skills of vital-sign checking and physical assessment to evaluate the patient condition/drug efficacy or prevent adverse reactions to drugs. To promote the acquisition of these skills, we prepared simulation programs with an emergency-care simulator, which facilitate the reproduction of excess-dose drug administration/condition changes. We used an emergency-care simulator equipped with a personal computer. General condition was established using the blinking velocity, cardiac/respiratory sounds and blood pH as parameters. As a results, concerning drug administration, the simulation programs facilitated the reproduction of symptoms related to the excess-dose insulin administration. With respect to changes in the condition, it facilitated the reproduction of asthma, hyperglycemia, and hemorrhage. This facilitated the palpation-, visual perception-, and auditory perception-mediated understanding of changes in the patient condition through fingertips and warnings/alarms on the monitor. Evaluation of the student for these program contents increased significantly ($p<0.01$). These programs can be downloaded *via* the Internet. Experience regarding excess-dose drug administration/condition changes with an emergency-care simulator is useful for checking patients' vital signs, evaluating the drug efficacy, and confirming adverse reactions to drugs. By the practice of these programs, we can teach pharmacy students how to check for vital signs (pulse palpation, auscultation, blood pressure measurement, and electrocardiography) in a school setting, not a hospital setting. Mastering these techniques may allow pharmacy students to determine the efficacy of a drug and adverse reactions.

Key words——simulator; vital sign; physical assessment; excess-dose drug administration; condition change; simulation

INTRODUCTION

Conventional pharmacy education has focused on the acquisition of basic pharmaceutical knowledge, and clinical pharmaceutical education was not a major aim. However, both professional and clinical knowledge are needed in a real medical scene. The conventional Japanese pharmacists are different from doctors and nurses in that they do not directly examine patients. However, it is now acknowledged that pharmacists should monitor patient vital signs in order to evaluate drug treatment effects and adverse events. In other words the belief that ''a pharmacist must not touch the patient'' is decreasing. The monitoring of vital signs is a fundamental activity for medical personnel; it is a common language. Pharmaceutical education at Kyushu University of Health and Welfare, School of Pharmaceutical Sciences aims to train pharmacists who can monitor vital signs to confirm the effects and adverse events of drugs.[1–3]. We perform experience-based, bedside education as part of our clinical pharmacy training. In the bedside training, we perform confirmation of the route of administration, rectal drug administration, subcutaneous/intramuscular drug administration, simulate drawing of blood, vital-sign monitoring using pharmaceutical universal training model, and vital-sign monitoring devices and various simulators. We prepared simulation programs with an emergency-care simulator, which facilitate the reproduction of excess-dose drug administration/condition changes this time. This facilitated the palpation-, visual perception-, and auditory perception-mediated understanding of changes in the patient condition through fingertips and warnings/alarms on the monitor. In this thesis, we report preparation situation of simulation programs which enables students to experience drug administration-/condition change-simulation using an emergency-care simulator.

*e-mail: j-tokunaga@phoenix.ac.jp

MATERIALS AND METHODS

Preparation of Simulation Programs with an Emergency-care Simulator We used an emergency-care simulator (an adult model ECS ''Stan®'', I.M.I Co., Ltd., manufactured by METI, Inc., U.S.A.) (Fig. 1). This simulator can reproduce vital sign changes and disease-related conditions of the human body, since a computer creates reactions to treatments such as drug administration and ventilation based on pharmacokinetic/-dynamic data. We initially developed the simulation program flow chart and then programmed the simulation parameters into the emergency-care simulator software. About simulation programs to preparate, the reproduction of symptoms are drug administration: excess-dose insulin administration. With respect to changes in the condition, the reproduction of symptoms are as follows: asthma; hyperglycemia; hemorrhage. The patient general condition was established using the blinking velocity, cardiac/respiratory sounds and blood pH as parameters. The heart rate was adjusted based on the heart-rate coefficient and fixed heart rate. The blood pressure was adjusted based on the systemic vascular resistance factor, venous capacity factor, and blood volume. In addition, the general condition was adjusted based on baroreceptor gain influencing the heart rate and mean systolic arterial pressure. The emergency-care simulator facilitates the confirmation of cardiac/respiratory/bowel sounds and common carotid (60 mmHg or more)/radial (90 mmHg or more)/brachial (70 mmHg or more)/femoral (80 mmHg or more)/popliteal (80 mmHg or more)/dorsal foot (80 mmHg or more) artery pulses.

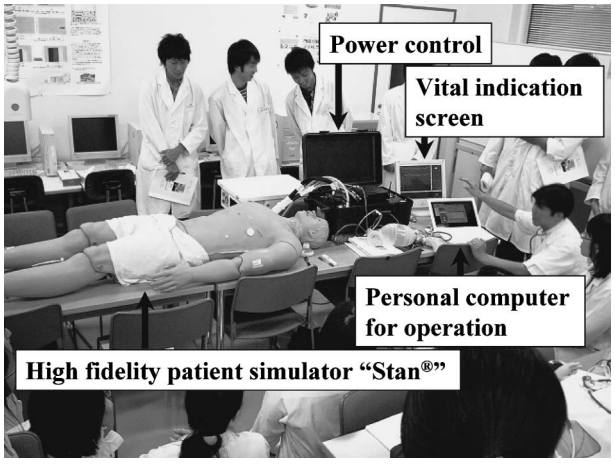

Fig. 1. Emergency-care Simulator ''Stan®'' (left) and Its Composition (right)

Enforcement of Program Contents and the Evaluation by the Students These programs were conducted involving 50 students taking a hospital pharmacy course in the fifth grade in the Faculty of Pharmacy. We arranged for a group that consisted of six to eight students and one teaching staff member as an operator to experience a program for 90 minutes per time. The demonstration for 90 minutes was carried out eight times over 2 days so that all students could experience it. A teaching staff operated the reproduction of these programs, and students could experience confirmation of the pulse rate, examination of the cardiac/respiratory sound by a stethoscope, and monitoring of blood pressure/SpO_2/blood pH. Their knowledge level of each program based on self-evaluation was retrospectively examined before and after the demonstration. The evaluation was conducted using the visual analog scale (VAS).[4] The programs of interest were: (1) symptoms of excess-dose insulin administration, (2) asthma symptoms, (3) hyperglycemia symptoms, and (4) hemorrhage symptoms. To clarify their knowledge, the left-most column indicated ''Not understand at all'', and the right-most column indicated ''Fully understand'', and we asked the students to indicate their knowledge level by drawing a straight line with a highlighter pen. Regarding data on knowledge obtained from this, the length of the line which the responder drew with the highlighter pen as a percentage of the total line length was calculated for each item. We did not perform an examination using an emergency-care simulator, we investigate the understanding degree only.

Statistical Analysis We used a Wilcoxon *t*-test and analyzed the difference of practice before and after in the understanding degree of each program contents.

RESULTS

Excess-dose Insulin Administration The initial baseline (71 bpm, 114/51 mmHg, SpO_2: 99%) condition reflects the health status of healthy adults. It can be switched to the condition established for diabetics (99 bpm, 153/85 mmHg, SpO_2: 97%) by clicking the mouse. With the subsequent clicking operation, it gradually changes to the condition after excess-dose insulin administration. Insulin shock (102 bpm, 81/44 mmHg, SpO_2: 97%) occurs approximately 90 se-

conds after administration, causing convulsive attacks. Then, an alarm sounds, indicating SpO_2 reduction, with the eyes closed (104 bpm, 79/44 mmHg, SpO_2 measurement: impossible). The condition can be changed to ventricular tachycardia (VT) by clicking the mouse. Convulsion decreases, leading to ventricular fibrillation (VF). This program facilitated the development of sinus rhythm with the clicking operation, because enforcement of appropriate defibrillation, and the intravenous injection of 20% glucose or administration of glucagon/potassium preparations may result in recovery in some cases.

Asthma The flow chart of a simulation program regarding asthma is shown in Fig. 2. The actual program is presented in Fig. 3. When clicking the mouse, the baseline (72 bpm, 114/52 mmHg, SpO_2: 99%) condition changes to initial asthma symptoms. As a result, stridor can be confirmed using a stethoscope. Furthermore, the pulse rate gradually increases, and the blood pressure decreases (88 bpm, 127/68 mmHg, SpO_2: 93%). An alarm sounds, indicating SpO_2 reduction. Subsequently, there are changes in the pulse rate, blood pressure, and SpO_2 (123 bpm, 147/87 mmHg, and 75%, respectively), leading to loss of consciousness, with the eyes closed. The administration of adrenaline or aminophylline with the clicking operation transiently increases the pulse rate and blood pressure (142 bpm, 158/102 mmHg, SpO_2: 77%), resulting in recovery, with the eyes open (93 bpm, 120/69 mmHg, SpO_2: 96%). This program was established so that the administration of adrenaline for primary symptoms or a pulse rate/blood pressure of 120 bpm/140 mmHg or more might result in recovery.

Hyperglycemia The baseline (65 bpm, 121/50 mmHg, SpO_2: 98%, pH: 7.45) condition automatically changes to hyperglycemia symptoms after 30 seconds. Initially, an increase in the pulse rate and decrease in the blood pressure are observed, with a blood pH value of 7.06. The eyes are closed, leading to coma (78 bpm, 102/50 mmHg, SpO_2: 95%, pH: 6.97). The clicking operation at this point facilitates the appearance of convulsive attacks. After coma, the eyes can be opened by clicking the mouse so that recovery may be achieved (107 bpm, 75/44 mmHg, SpO_2: 99%, pH: 7.47). This operation should be carried out when physicians or pharmacists indicate the intravenous injection of insulin/sodium bicarbonate or administration of various vasopressors.

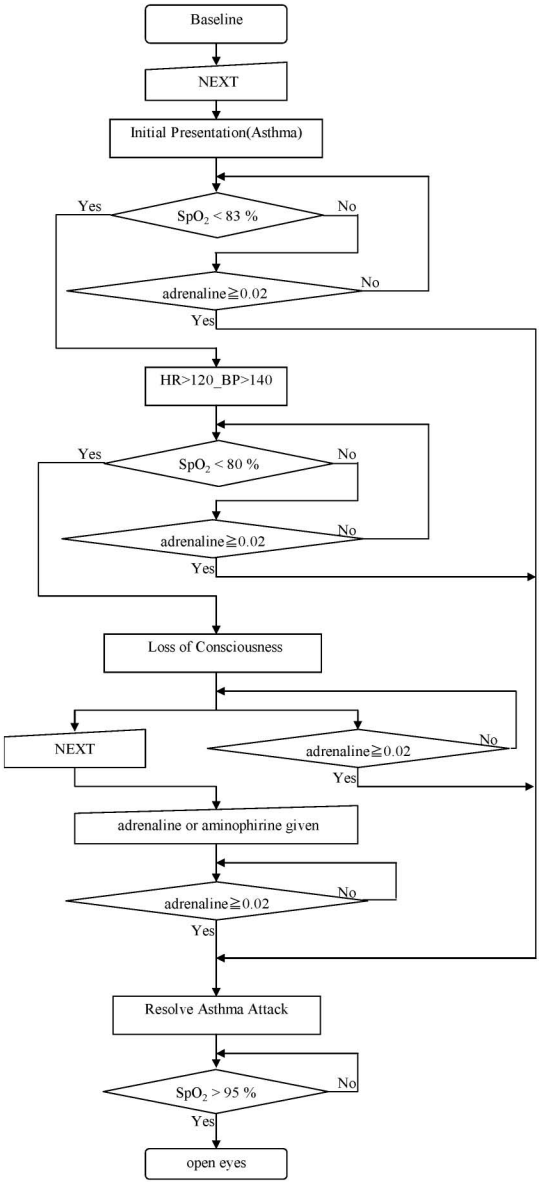

Fig. 2. Flow Chart of a Simulation Program for Asthma

Hemorrhage When clicking the mouse, the baseline (74 bpm, 114/51 mmHg, SpO_2: 99%) condition gradually changes to hemorrhagic symptoms. Initially, an increase in the pulse rate and decrease in the blood pressure are observed (115 bpm, 84/47 mmHg, SpO_2: 97%). Subsequently, the eyes are closed, and tachycardia occurs. An alarm sounds, indicating SpO_2 reduction (42 bpm, 62/14 mmHg, SpO_2 measurement: impossible). The clicking operation at this point makes the eyes open, facilitating recovery (75 bpm, 112/52 mmHg, SpO_2: 98%). This process was established so that appropriate hemostasis and the administration of blood preparations might result in resuscitation. Our scenarios are available for down-

▼1 Baseline
▼*Event*
set Ischemic Index Sensitivity **to** 0.45
▼*Transitions*
▼2 Initial Presentation(Asthma)
▼*Events*
set Resistance Factor: Systemic Vasculature **to** 1.50 **over** 30 seconds
set Contractility Factor: Right Ventricle **to** 1.2 **over** 30 seconds
set Contractility Factor: Left Ventricle **to** 1.2 **over** 30 seconds
set Heart Rate Factor **to** 1.2 **over** 30 seconds
set Breath Sounds Volume **to** 2.0
set Breath Sounds **to** Wheezing
set O_2 Consumption **to** 600 mL/min **over** 30 seconds
set Shunt Fraction **to** 0.50 **over** 30 seconds
set Baroreceptor Gain (Cardiac) Factor **to** 0.50 **over** 30 seconds
set Respiratory Rate Factor **to** 2 **over** 30 seconds
▼*Transitions*
if SpO_2 < 83 % **then go to** *HR>120_BP>140*
if adrenaline ≧ 0.02 nanogram/mL **then go to** 5_*Resolve_Asthma_Attack*
▼3 Loss of Consciousness
▼*Events*
set Eyes: Blink Control **to** Eyes Closed
▼*Transitions*
if adrenaline ≧ 0.02 nanogram/mL **then go to** 5_*Resolve_Asthma_Attack*
▼4 ** adrenaline or aminophirine given
▼*Events*
give bolus of adrenaline 10 microgram
▼*Transitions*
if adrenaline ≧ 0.02 nanogram/mL **then go to** 5_*Resolve_Asthma_Attack*

▼5 Resolve Asthma Attack
▼*Events*
set Breath Sounds Volume **to** 1 **over** 1 minute(s)
set Breath Sounds **to** Normal
set Shunt Fraction **to** 0.1 **over** 1 minute(s)
set O_2 Consumption **to** 200 mL/min **over** 1 minute(s)
set Contractility Factor: Right Ventricle **to** 1 **over** 1 minute(s)
set Contractility Factor: Left Ventricle **to** 1 **over** 1 minute(s)
set Ischemic Index Sensitivity **to** 0.25 **over** 30 seconds
set Heart Rate Factor: **to** 1.2 **over** 30 seconds
▼*Transitions*
if SpO_2 > 95 % **then go to** *6_open_eyes*
▼6 open eyes
▼*Events*
set Eyes: Blink Control **to** Automatic
set Respiratory Rate Factor **to** 1 **over** 30 seconds
set Heart Rate Factor **to** 1 **over** 30 Seconds
▼*Transitions*
if Time in State > 10 seconds **then go to** 1_Baseline
▼HR>120_BP>140
▼*Events*
set Ischemic Index Sensitivity **to** 0.3
set Heart Rate Factor: **to** 1.45 **over** 12 seconds
set Contractility Factor: Left Ventricle **to** 1.4 **over** 12 seconds
set Contractility Factor: Right Ventricle **to** 1.4 **over** 12 seconds
▼*Transitions*
if SpO_2 < 80 % **then go to** *3_Loss_of_Consciousness*
if adrenaline ≧ 0.02 nanogram/mL **then go to** 5_*Resoive_Asthma_Attack*

Fig. 3. Simulation Program for Asthma
The programs are available to be used only in the emergency-care simulator.

Table 1. Change in the Degree of Understanding of Each Program Contents before and after the Practice

Self-evaluation of program contents	Degree of understanding (%)	
	Before	After
Excess-dose insulin administration	39±3.1	66±2.7**
Asthma	46±3.0	72±2.8**
Hyperglycemia	31±2.8	63±3.0**
Hemorrhage	36±3.1	62±2.8**

Each value shows mean±S.E. (n=50). ** p<0.01 (Wilcoxon t-test).

load from the Kyushu University of Health and Welfare (https://www.pharm.phoenix.ac.jp/~cp2/dl.html).

Evaluation of the Student for the Program Contents Table 1 shows the change in the level of knowledge for each program before and after the demonstration. As a result of evaluating the necessity, the line rates for symptoms of excess-dose insulin administration, asthma symptoms, hyperglycemia symptoms, and hemorrhage symptoms were significantly increased from 39% (before the demonstration) to 66% (after the demonstration), 46% to 72%, 36% to 62%, and 31% to 63%, respectively (p< 0.01).

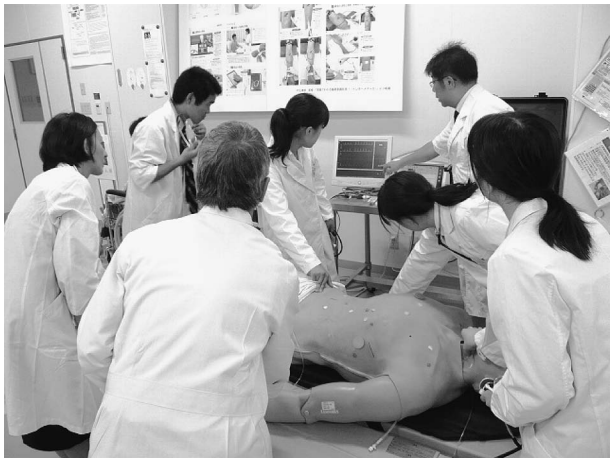

Fig. 4. Monitoring Pulse Rate and Other Vital Signs Using "Stan®"

DISCUSSION

In these simulation programs, we utilized the function of this simulator, such as eye-opening/closing, stridor, and deep breathing functions, in addition to changes in the pulse rate, blood pressure, SpO_2 and blood pH on the monitor. As a result, we could prepare 4 simulation programs. This facilitated experience-based education regarding excess-dose drug administration and acute-phase condition changes, which cannot be observed in pharmacists' routine

practice (Fig. 4).

As treatments for the excess-dose insulin administration, hyperglycemia, and hemorrhage, various agents may be administered; therefore, the programs were established so that recovery might be achieved through the clicking operation. Concerning drug administration for asthma, adrenaline therapy, as a first-choice regimen, was included in the programs. We devised the hyperglycemia symptom to be able to reproduce the state of the acidosis, because of blood pH declined to the acidity. The evaluation of the student for these program contents increased significantly ($p<0.01$). However, we do not analyze objective learning effects (knowledge, improvement of the skill level) of students using simulation programs. It will be necessary to examine the objective learning effects using an emergency-care simulator in future.

For the current state of the pharmacy education using the simulator, Seybert *et al*. reported that the simulator had been used to acquire the skill of blood pressure measurement for the student in the PharmD course in U.S.A.[5] However, the simulator education to be able to experience the various condition changes by programming the drug administration and condition change, *etc*. has just started.[1,2] In such situations, other institutions provide training programs for pharmacists to learn how to confirm vital signs. A physical assessment model "Physico®" (Kyoto Kagaku Co., Ltd., Japan) is used for pharmacists at the Department of Pharmacy, Gunma University Hospital and a workshop is held for the measurement of the vital signs.[6] In addition, the university which used an emergency-care simulator and measured vital signs in a role playing form, came to be seen.[7] Therefore, cooperation of a doctor is essential to pharmacy education in the future. The Japanese Society of Hospital Pharmacists requests education for new pharmacist duties in the confirmation of vital signs to College of Pharmacy. On the other hand, they also have policies that emphasize lifelong training workshops for pharmacists in a real medical scene.[8] Therefore, we propose that the College of Pharmacy and Pharmacist Association should institute training in confirmation of vital signs for lifelong training workshops, as well as pharmacy students.

As medical personnel, pharmacists must learn basic vital-sign monitoring and emergency care, and it is for this reason that we prepared experience-based education programs employing an emergency-care simulator. As the programs can be repeatedly used, it is also possible to improve skills in a short period. By the practice of these programs, we can teach pharmacy students how to check vital signs (pulse palpation, auscultation, blood pressure measurement, and electrocardiography) in a school setting, not a hospital setting. Mastering these techniques may allow pharmacy students to determine the efficacy of a drug and adverse reactions.

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