Original Article

Teaching cardiopulmonary resuscitation with simulators. A cost-effectiveness study

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ABSTRACT

Aims: The aim of the study was to assess if the number of students who pass an advanced life support course is higher using a simulator for resuscitation training compared with usual resuscitation training.
Methods: The students were randomized for practical classes and evaluations in two groups of 250 members: the first group was allocated to use a last-generation resuscitation simulator and the other to use standard manikins. At the same time, 125 students in each group received a handbook to be revised before the course. The courses were delivered during the years 2003 and 2004 in the four provinces of Galicia.
Results: The rate of students who passed the course was different using simulator training or normal training (88% versus 78%; p < 0.001). The training cost per-student was three times higher with the resuscitation simulator. Thus, the costs of passing the course were 457.23 and 481.77€€ for normal training with and without previous preparation, respectively, versus 1283.11 and 1483.11€€ for resuscitation simulator with and without previous preparation, respectively. The rate of students who passed the course additional from 76% to 90% with previous preparation (p < 0.001) and the costs were low. Moreover, this increase was more marked in students who made the course with simulator (from 80% to 96%, p < 0.001) compared with those who used classic manikins (from 72% to 84%; p < 0.05).
Conclusions: The most cost-effective strategy for resuscitation training in primary care physicians and nurses is usual training with previous preparation. We must look for mechanisms to reduce the costs derived from using resuscitation simulators. Independently of the kind of training, the students must always undergo previous preparation.

Key Words: *Medical simulation. Advanced life support. Costs. Manikin. Integrated practice.*

RESUMEN

Estudio coste-efectividad de la enseñanza de la reanimación cardiopulmonar con simuladores

Objetivos: El estudio pretende ver si existe un mayor número de alumnos que superan un curso de soporte vital avanzado con un simulador frente al entrenamiento normal.
Métodos: Se ha dividido a los alumnos de forma aleatoria en dos grupos de 250 miembros cada uno: en uno se utilizan para las clases prácticas y para la evaluación un simulador de última generación y en el otro los maniquíes habituales. Al mismo tiempo a la mitad de los alumnos de cada grupo se les entrega un manual para la preparación previa del curso. Esta asignación se realiza de forma aleatoria a 125 alumnos de cada uno de los grupos. Los cursos se han llevado a cabo durante los años 2003 y 2004 en las cuatro provincias de Galicia.
Resultados: Se encuentran diferencias de aprobados según se use un simulador (88%) o el entrenamiento normal (78%; p < 0,001). El coste por alumno es unas 3 veces más elevado con simulador. Así, un aprobado con el entrenamiento normal supone 457,23€ con preparación previa, y 481,77€ sin ella frente a los 1.283,11€ y 1.483,11€ del simulador. La preparación previa eleva el número de aptos de un 76% a un 90% (p < 0,001) con un coste bajo, y este incremento es más marcado para aquéllos que realizan el curso con simulador (de 80% a 96%; p < 0,001) que para quienes lo realizan con los maniquís clásicos (de 72% a 84%; p < 0,05).
Conclusiones: La mejor estrategia coste-efectividad para el entrenamiento en técnicas de reanimación para los médicos y enfermeras de atención primaria es con entrenamiento normal y preparación previa. Debemos buscar mecanismos para disminuir los costes originados por los simuladores. En todos los casos de entrenamiento se debe realizar una preparación previa de los alumnos.

Palabras clave: *Simulación médica. Soporte vital avanzado. Costes. Maniquí. Práctica integrada.*

INTRODUCTION

Every year cardiopulmonary resuscitation is applied to 9500 cases of cardiorespiratory arrest in Spain (24/100,000 inhabitants/year), a rate which is currently increasing[1]. Between 811 and 960 premature deaths at hospital[2] discharge from are avoided annually prevented every year. This gives us an idea about the importance of training healthcare professionals in cardiopulmonary re-

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Received: 5-2-2007
Accepted: 27-6-2007

suscitation (CPR) techniques[3-5]. These are the main reasons led took the European Resuscitation Council (ERC) to recommend the training of basic and advance CPR techniques to all medical and nursing professionals with the possibility of encountering a cardiorespiratory arrest (CA) in their everyday work in their 2001[6] guidelines, and later in 2005[7]. This training must be done through courses of at least 20 hours of duration and professionals must take update courses every two years[8]. CPR courses should consist of one part of theory and another part of practice in which CPR techniques are practised on dummies specially designed for this purpose.

CPR training has been one of the most largely developed subjects among healthcare professionals[9-11] in the last fifty years of the twentieth century[12]. The new century has brought us the generalisation of training in modern comprehensive patient simulators with possibilities for transport and affordable costs. Until that time the existing simulators could only be used in large premises where they were placed permanently and required a considerable amount of auxiliary material to make them work. In general, they originated from adaptations, with different results, from flight simulators used for training pilots[13]. However, they could not reproduce the physiopathological characteristics of patients - except for very limited parameters[14]. Simulation allows training not only in scientific and technical aspects but also in cognitive and human factors. Although the experience with this type of systems is short, it seems clear that its use can accelerate the acquisition of skills and knowledge in managing complex problems and promote a better clinical performance[15,16].

This study had a double purpose. On one hand, our aim was to know if the higher percentage of pass grades obtained in the course with simulator could justify the investment that entails the purchase the equipment. On the other hand, we wanted to know if studying a previous material before taking the course influenced the percentage of pass grades compared to taking the course with simulator previous material.

MATERIAL AND METHOD

This cost-effectiveness study involved the use of data from the advanced life support (ALS) course taught at the centre for training in emergency and disaster in Galicia (Centro de Formación en Urgencias, Emergencias y Catástrofes) within the public foundation for emergency services Fundación Pública Urgencias Sanitarias de Galicia-061 (FPUS-061). As the ALS courses are the most frequently requested, they were used them to study the number of students obtaining pass grades.

The course consists of 20 hours divided in to four sessions of 5 hours each. Ten 10 hours are dedicated to theory and are taught in the classroom and 10 hours are devoted to practice using dummies or patient simulators for practise in CPR scenarios. In these practical sessions, the students are divided into three groups, each directed by one instructor. At the end of the course students are assessed in both theoretical and practical skills. The theory exam consists of 40 multiple choice questions with only one correct answer requiring 30 correct answers to pass the test. Wrong answers do not count negatively. Then the practical exam is carried out with the same material used for the practical sessions. Students must be able to adequately manage the situations presented by the instructor. Both tests must be passed in order to pass the course. The theory exam paper has been elaborated by the instructors themselves and has been validated by a psychometric study to confirm that it measures the desired objectives, that is, knowledge of CPR techniques. The theoretical exam involves the desig of clinical cases. Which have also been elaborated by the centre instructors and analysed be repeated reproduction and evaluation of the critical points loading to students failure as these would be lethal for patients. They are included in a standardised form for practical assessment. In all these courses, the same practical cases and assessment tests have been given to the participating students.

The teachers take an annual simulation training course in which they work with the software installed in the simulators and become familiarised with the peridical updates by the manufacturer.

This study attempted to establish the possible significant differences on applying a cost-effectiveness study in a group trained using conventional training techniques and in another group trained with medical simulation techniques.

The students were randomly divided into two groups of 250 participants each. This constitutes 10 courses with 25 students in each group. In one group, conventional dummies were used for practical lessons and assessment (strategy A) and in another group this is done using a last generation clinical simulator (strategy B). At the same time, half of the students in each group (125) were given, at least 15 days before the course, a handbook[17] and previous instructions on its use and the dynamics of the course. The rest of the students did not receive any previous material and came to the course only knowing that it was a CPR course. They were the recommended to of consult certain bibliography and to be familiar with the subject of the course to take full advantage of it, but the handbook was only given at the beginning of the course. This was given randomly to 125 participants in each group (125 in strategy A and 125 in strategy B). Each edition of the course was randomised for previous or no previous preparation and strategy A or strategy B. There was no assignation of different students in every edition of the course to avoid differences if there was any external interference during the development of the course.

TABLE 1. Characteristics of dummy used in training courses

- Oral and nasal intubation, laryngeal mask and combitube.
- Defibrillation and ECG monitoring.
- Venous access.
- Infusion of fluids.
- Synchronised carotid pulse with variable intensity.
- Flexibility for coming out of defibrillation.
- Cardiac rhythmy simulator:
- Battery-powered ECG simulator.
  - 30 cardiac rhythms.
  - 17 modified rhythms.
  - 7 paediatric rhythms.

TABLE 2. Characteristics of the medical simulator used in the courses

- Airway that allows simulation of a large number of complications.
- Pneumothorax and insertion of drainage tube.
- Carotid, femoral, radial and brachial pulse.
- Cardiac, pulmonary and intestinal sounds for auscultation.
- Blood pressure and Korotkoff sounds.
- 2,500 variants of heart sounds, defibrillation and transcutaneous pacemaker.
- Intravenous access.
- Genitalia of both sexes and insertion of catheters.
- Simulated monitor that allows considering different parameters and evolution during the course of the clinical case.
- Can be handled via PC or remote control.

The characteristics of the conventional dummy and the simulator are shown on Tables 1 and 2.

The different editions of the courses took place during 2003 and 2004 in the four Galician provinces according to the distribution shown in Table 3.

The cost of each strategy was quantified taking into account a higher use of consumables, the recoup of non-disposable equipment that is much higher with the simulator and also the transport of the simulator that takes up more space. The differences between the cost of sending previous material or not was also assessed, with few differences because the material is not expensive. This is shown in Table 4.

The following is a step-by step explanation of direct and structural costs to estimate the final cost of the course depending on the training and teaching material used.

TABLE 3. Number of courses and students per province

Province	City	Courses	Students
A Coruña	A Coruña	2	50
	Ferrol	3	75
	Santiago de Compostela	4	100
Pontevedra	Pontevedra	3	75
	Vigo	3	75
Lugo	Lugo	3	75
Ourense	Ourense	2	50
TOTAL		**20**	**500**

1. Direct costs

a. Recoup of Non-disposable Equipment

We considered the costs of recoup and maintenance of the medical equipment necessary to teach the courses, attributing the corresponding part in proportion to each course considering the number of hours that the equipment was actually used.

b. Renting

We considered the cost for renting the room where the course is taught during 10 hours. It has a capacity for 30 students and it is equipped with projection screen, LCD projector, table, auxiliary tables for clinical material, portable table for defibrillator, TV, video/DVD player and blackboard. We also included the 3 rooms necessary for the practical sessions, to work in groups with the dummies or in the simulators.

c. Consumables

We considered the material necessary used during work groups as a whole to carry out an ALS course.

d. Pharmacy

We considered the maximum amount of material that can be used in one course and that has to be replaced for the next one as the packaging is opened so that the practice is as similar to a real-life scenario as possible.

e. Teaching material

Students from both groups are given the handbook on advanced life support (Manual de Soporte Vital Avanzado) published by the Spanish Commission for CPR (Comité Español de RCP). The participants in the simulator group are also sent an annex with the characteristics of the simulator that they are going to use and brief instructions on its use. The information is sent to reach participants at least 15 days before the start of the course.

TABLE 4. Costs of the courses

Cost of courses																	
		Material						Instructors									
								Hours of theory			Hours of practice				Struc-ture	Total cost	Price per unit
	Number of students	Rec.	Rent	Con.	Phar	Teaching Mat.	Accred	Tot	€ per hour	Cost	Tot	Prof	€ per hour	Cost			
CONVENTIONAL (Strategy A)	25	1 599.43	75	80	12	37	0,9	10	48.1	480.8	10	3	30.05	902	4 490.88	8 667.11	346.68
SIMULATOR (Strategy B)	25	22 391.95	75	80	12	45	0,9	10	48.1	480.8	10	3	30.05	902	4 490.88	29 662.13	1 186.49

Rec.: Recoup. Con.: Consumables. Phar: Pharmacy. Teaching Mat.: Teaching Material. Accred: Accreditation. Tot: Total.

Participants in the group with no previous preparation are given the handbook on the first day of the course.

f. Accreditation

The accreditation is given through the diplomas issued to the students that pass the course by the office of the National Plan for CPR (Plan Nacional de RCP) as well as through a diploma issued by the training centre of the FPUS-061 that includes the 5.1 credits assigned by the Commission for Continuing Education of Healthcare Professions (Comisión Autonómica Formación Continuada de las Profesiones Sanitarias).

g. Faculty

An instructor is needed for theoretical lessons and they are paid 48.1€ per hour taught. These tuition fees have been approved by the management of the foundation and are defined according to the level of difficulty of the course in three categories. The present course here belongs to level II. The practical sessions require the presence of three instructors at the same time for the three work groups. Each on of these instructors is paid 30.05€ per hour.

Instructors are accredited by National Plan for CPR (Plan Nacional de RCP) and although most are professionals of the FPUS-061, there are also external instructors that are paid equally.

2. Structural costs

These are the conventional costs of training services (staff, premises equipped for training activities, etc.) and are attributed to the different courses-products according to the number of hours of each course. The common costs for activities aimed at the structure of the foundation (cleaning, communications, supplies, management units, etc.) are also included attributed as an estimate and proportional to the weight of the teaching staff within the foundation, that is approximately 2.5%.

Statistical analysis was done using the chi-square test and with are significant differences being considered with a p value less than 0.05.

RESULTS

Among the 500 students, 341 (68.2%) were women and 159 (31.8%) were men with 283 being medicine graduates and 217 nursing professionals. All were statutory staff of the healthcare system, temporarily appointed to a statutory post or substitutes in primary care (PC). The mean age was of 43, ranging from 24 to 61 years (SD ± 13). One hundred eighty-one had taken a course like this previously (36.2%) and only 36 had done so during the last 2 years (7.2% of the total sample) that is the period recommended by the ERC to maintain CPR skills. In terms of the sex of the participants, the distribution in both groups was homogeneous (p = NS). The percentage of doctors in strategy B (medical simulation) was significantly higher to that in strategy A (162/250 = 64.8% vs. 121/250 = 48.4%; $p < 0.001$).

The distribution of students in the different strategies and the final results are shown in Figures 1 and 2. Comparison between the number of students obtaining a pass grade in the different groups is shown in Table 5. The percentage of pass grades was statistically higher with strategy B (88%) than with strategy A (78%; $p < 0.001$). The presence of previous preparation increased the number of pass grades from 76% to 90% ($p < 0.001$) and being more patent for those taking the course with strategy B (from 80% to 96%; $p < 0.001$) than for those taking the course with strategy A (from 72% to 84%; $p < 0.05$).

Finally, on calculating the cost of each pass grade with the different methods, a 2.8 to 3.1 fold higher cost was observed for those participants included in strategy B (with simulator; Table 6).

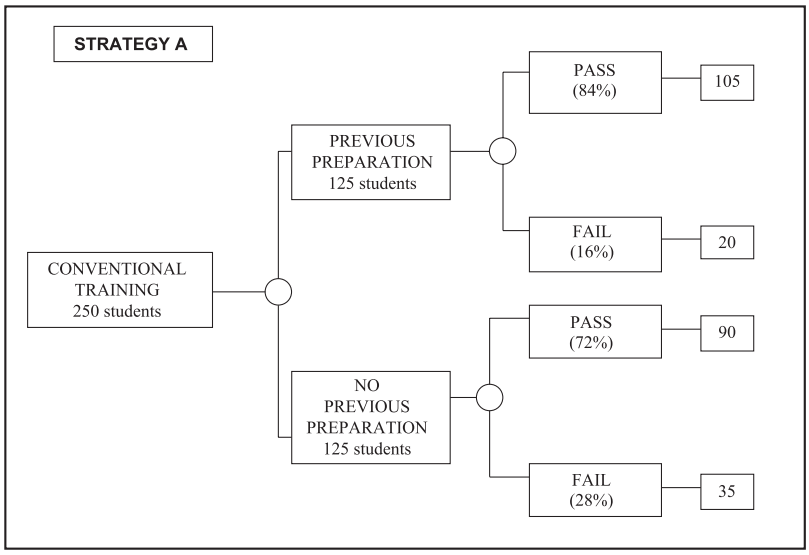

Figure 1. Conventional training strategy.

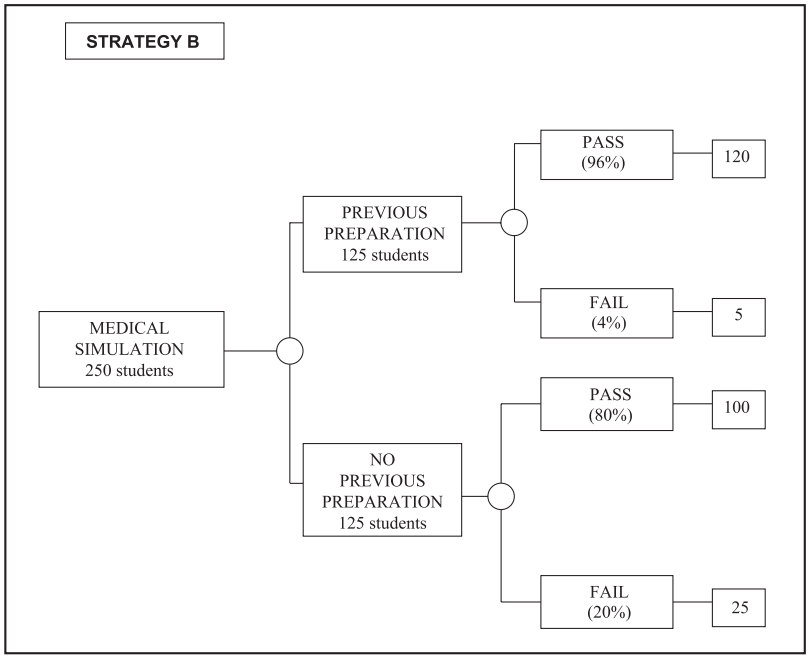

Figure 2. Simulator training strategy

DISCUSSION

The participants of this study were older (10 more years) than those in the other only series assessed in the use of simulators[18] in Spain to date. This may be due to the greater professional experience of the participants and the different backgrounds of origin while the other study only included emergency medicine doctors working in hospitals. A possible limitation of this study is the higher number of doctors in our study in the simulator group that may have influenced the number or pass grades in this group. However, this may have minor relevance because, as pointed out by the different scientific societies involved, ALS training requires the same course for doctors and nurses and there is no difference in terms of techniques, treatment or even group leadership, which must be carried out by the most experienced individual regardless of their professional category. Besides, the results obtained do no differ from those observed in previous studies on training with simulators[19] in which, generally, doctors doing their internship were assessed[20,21] or the training was even used for access to internship placements.

The total number of pass grades is 415, representing 83% of the total number of students taking the exam. Among those, 195

TABLE 5. Analysis of the influence of training type on the number of pass grades

		Total	Conventional training	Medical simulation	p
All participants					< 0.001
	Pass	415 (83%)	195 (78%)	220 (88%)	
	Fail	85 (17%)	55 (22%)	30 (12%)	
Participants with previous preparation*					< 0.01
	Pass	225 (90%)	105 (84%)	120 (96%)	
	Fail	25 (10%)	20 (16%)	5 (4%)	
Participants with no previous preparation*					0.18
	Pass	190 (76%)	90 (72%)	100 (80%)	
	Fail	60 (24%)	35 (28%)	25 (20%)	

*p < 0.001 comparison of presence or not of previous preparation.

(78%) were in the conventional training group and 220 (88%) were in the simulation group. In agreement with previous experiences[22] showing a higher increase of success among participants trained with simulators[23,24], a higher increase was expected in the number of pass grades with the simulator in the present study. Although 83% of pass grades for the whole sample may seem a high percentage, in the quality standards of the training centre of FPUS-061, that the minimum percentage of success should be of 85%. A lower, pass rate an internal audit would require to determine the circumstances leading to this low rate (defective material, lack of consumables, non compliance with schedule, factors related to the instructor, etc.). In the conventional training group only 78% (195/250) of the students passed the assessment, while in the simulator group the average rate was higher and fulfilled our recommendations for quality with 88% (220/250) of pass grades. Statistical significance of p = 0.003, was achieved that is, for every 11 students trained with a simulator, obtain one more pass grade (CI 95%: 7 to 29).

Previous preparation markedly improved pass rates in those who took the course with the simulator. In this case, for every 8 students that had received previous preparation, one more pass grade was achieved (CI 95%: 5 to 14). However, it is clear that, from an academic point of view, it is better to carry out the course with medical simulators and that the number of pass grades in the courses increases significantly if there is also previous preparation.

If we combine the data of pass and fail grades with the costs originated by the different courses, the costs of obtaining a pass with the conventional techniques or with the simulators can be calculated. The data obtained (shown in Table 6) confirm that there are differences in the number of pass grades depending on whether a simulator or conventional training is used. Moreover, the cost per student is of between 2.8 and 3.1 times higher using a medical simulator. A pass grade with conventional training entailed 457.23€ with previous preparation and 481.77€ without, while a pass with simulator training costs 1283.11€ with previous preparation and 1483.11€ without. In addition, previous preparation increased the number of pass grades in the two groups (simulation/conventional training). In fact, that in both strategies the costs for each pass grade decreased in the groups with previous preparation. In the group with conventional training, 24.54€ are saved per each student that passes. In the simulator group, 200€ are saved per each student that passes. However, this previous preparation cost only 37.2€ and 45.3€, respectively.

It seems necessary to determine the element that makes the training with a simulator much more expensive than training. Besides the cost of the simulator itself, the concept of recoup we must be consider red that is high due mostly to the simulator being very specific for this type of courses, while the dummies used for conventional training are used more frequently. In order to make the training with simulators more profitable, they should be used in a higher number of our training activities as this would lower the recoup and reduce the cost per student.

It is important to point out that, at the time this study was carried out, there was no other simulator with the same characteristics in the Spanish market. Other simulators with similar features and competitive prices are currently being introduced. This will probably result in a decrease in current prices. If we can reduce expenses by acquiring cheaper simulators, using them in different types of courses and keeping them operative during most of the year, the difference in pass grades in the courses that use simulation techniques and the one with conventional techniques will be made profitable. Moreover, although the use of a simulator for ALS courses may be difficult to justify previously in term of costs, it is an ideal tool for assessing situations with patients with a severe condition and with high risk of CA. It allows checking the clinical evolution of an unstable patient and to assess the

TABLE 6. Total costs and mean ratios in training strategies

			Costs				
		Pass	Prep.	Train.	Ind. Totals	Totals	Average ratios
Conventional	p.p.	105	37.2	346.68	384.08	48 010	457.23
	No p.p.	90			346.88	43 360	481.77
Simulat.	p.p.	120	45.3	1 186.49	1 231.79	153 973.75	1 283.11
	No p.p.	100			1 186.49	148 311.25	1 483.11

Simulat.: Training with simulator. Prep.: Preparation. p.p.: previous preparation. Train.: Training. Ind.: Individual.

physiological responses to the different measures taken by the student. In addition, it does not require the direct intervention of the instructor to explain the changes and allows recording all the actions taken by the student in real time.

In conclusion, the best cost-effectiveness strategy for training medical and nursing professionals in CPR techniques in Galicia, at present and with current prices, is conventional training with previous preparation. Mechanisms to reduce the costs originated by simulators should be determined to there by reduce the expenses they originate with more frequent use. In all training cases, either with simulators or conventional dummies, students should receive previous preparation. Training simulators play an important role in the assessment of patients in emergency situations with unstable conditions and they entail an advance in the learning of CPR techniques or in the situations immediately previous to a cardiac arrest.

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