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Proficiency in cardiopulmonary resuscitation of medical students at graduation: a simulator-based comparison with general practitioners

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Summary

Question under study: There are no data on the preparedness of medical students at the time of their graduation to handle a cardiac arrest. The aim of the present study was to compare the performance in cardiopulmonary resuscitation of medical students at the time of their graduation with that of experienced general practitioners.

Methods: 24 teams consisting of three medical students and 24 teams consisting of three general practitioners were confronted with a scenario of a simulated witnessed cardiac arrest. Analysis was performed post-hoc using video recordings obtained during the simulation.

Results: Medical students diagnosed the cardiac arrest as quickly as general practitioners. Medical students were less likely to call for help in the initial phase of the cardiac arrest (14/24 vs 21/24; P = 0.002); had less hands-on time during the first 180 seconds of the arrest (52 ± 33 sec vs 105 ± 39 sec; P <0.0001); delayed the first defibrillation (168 ± 78 vs 116 ± 46 sec, P <0.007); and showed less directive leadership (4/24 vs 14/24 teams, P <0.007). The technical quality of cardiopulmonary resuscitation provided by medical students was partly better, but for no parameter worse, than that provided by general practitioners.

Conclusions: When confronted with a cardiac arrest, medical students at the time of their graduation substantially delayed evidence-based life-saving measures like defibrillation and provided only half of the resuscitation support provided by experienced general practitioners. Future research should focus on how to best prepare medical students to handle medical emergencies.

Key words: cardiopulmonary resuscitation (CPR); education; manikin; patient simulator; human factors; controlled trial; medical students; general practitioners

Introduction

Shortly after graduation young doctors may find themselves in the role of the physician responsible in a medical emergency. Mastering a complex medical emergency like a cardiac arrest requires the translation of knowledge and skills into timely and effective activity. As cardiac arrests are treated by teams rather than individual healthcare workers, teamwork-related issues like leadership or task distribution are likely to be important determinants of success [1, 2]. There are no data on how best to teach the various competencies required to successfully master a medical emergency. Thus, analysing the performance of medical students at the time of their graduation in cardiopulmonary resuscitation is important for assessing their preparedness for such situations, for identifying strengths and weaknesses of current curricula, and for highlighting specific targets for improvements in teaching.

For a variety of medical, ethical, and practical reasons the assessment of competencies in mastering a medical emergency in real patients is hardly possible. Medical simulation circumvents these obstacles and is ideally suited to evaluate competence in medical emergencies in a systematic way. Particular strengths of simulations are that 1) identical conditions can be presented to all participants, allowing meaningful conclusions about the competencies of cohorts; 2) scheduling is possible; and 3) there is no need to intervene in order to protect the patient in case of sub-optimal or even dangerous performance.

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Aim of the study: The aim of the present study was to compare the performance in cardiopulmonary resuscitation of medical students at the time of their graduation with that of experienced general practitioners.

Methods

Participants

The study was approved by the local ethical committee, and written informed consent was obtained from all participants. Data were collected in 2004 and 2005 at the simulation centre of the University of Basel. Medical students at the time of their graduation were offered the opportunity to participate in workshops in the patient simulator on a voluntary basis. Students were compared with an equal number of general practitioners regularly involved in emergency duties from all over Switzerland participating in workshops in the simulator centre on a voluntary basis. No formal previous training was required to participate and, during the workshop, no training or teaching was provided *prior* to the simulation. Thus, the participants' performance reflected their current knowledge and skills.

Participants were randomly allocated to teams. Each team consisted of a nurse and either three medical students or three general practitioners. The nurse is part of to the research team and was instructed to display a helpful attitude but to be active on request only. In each team, one person was randomly selected to be present from the start of the scenario, and the remaining two participants were summoned to help upon the onset of the cardiac arrest. Randomisation was such that in both conditions (students and general practitioners) an equal number of male and female participants were present from the start.

Simulator

A high-fidelity patient simulator (Human Patient Simulator, METI) was used. Features of this simulator include palpable pulses, spontaneous breathing with visible thoracic excursion, eyes with spontaneous lid movements, and a speaker in the mannequin's head that broadcasts the voice of an operator to give the impression that the "patient" can talk. A cannula was placed in a peripheral vein to allow for intravenous administration of drugs. A commercially available manual defibrillator was placed next to the bed. All participants received a 15 min structured instruction on the technicalities of the simulator before the scenario.

Scenario

Using a checklist, case history and instructions were given outside of the simulator room to the team member present from the start. The "patient" was a 66 year old man who had just completed an uneventful bicycle stress-test. During washing after the test the "patient" suddenly felt dizzy and was laid down on a bed. The instructions included the information that in the simulator room the participant would meet the "patient" and a nurse. The participant was instructed that he or she was the physician responsible for the patient, that support of the nurse was available on request, and that help from the two other colleagues was available on request.

Upon entering the simulator room, the participant encountered a talkative patient connected to a monitor showing sinus rhythm. The patient did not feel dizzy anymore but volunteered a detailed account of that episode. In addition, the patient complained of stiff muscles in both thighs. Two minutes after the participant had entered the simulator, a cardiac arrest occurred due to ventricular tachycardia displayed on the monitor. With the onset of the cardiac arrest, the patient closed his eyes, ceased speaking and breathing, and pulses were no longer palpable. In case the physician or medical student did not call for his or her colleagues within 15 sec, the two other members were sent to the simulator room by the researchers, so that all teams were complete ≤20 sec after the start of the cardiac arrest.

Regardless of any measures taken, the patient stayed in cardiac arrest for the first three min. To achieve a realistic termination of the cardiac arrest scenario we proceeded as follows: Between minutes 3 and 5 after the onset of the cardiac arrest, return of sinus rhythm was achieved by the first defibrillation occurring during that period, provided that intravenous epinephrine was administered at least once and cardiac massage had been performed. Between minutes 5 and 6 after the onset of the cardiac arrest return of sinus rhythm was achieved by the first defibrillation occurring during that period regardless of any previous action or lack thereof. To avoid a potentially traumatic experience in teams that did not achieve the return of sinus rhythm within six minutes, the "death" of the patient was prevented by the nurse who suggested appropriate measures. Return of sinus rhythm was accompanied by palpable pulses and spontaneous respiration.

A video-assisted debriefing concluded the simulation.

Data

The current guidelines for resuscitation during the study period, i.e., the guidelines of 2000 [3] were used as reference to evaluate the performance of the participants. Using frame-in-frame technology, the teams' performance and the monitor displaying the patient's vital signs were simultaneously recorded. Data analysis was made post-hoc by two independent observers using the videotapes recorded during simulations. The timing of events was defined to be in agreement if the difference between the two observers was less than five seconds. The shorter of the two timings was used for further analysis. Disagreements in the timing of events, behavioural ratings, and ratings of the quality of resuscitation measures between the observers were resolved by jointly reviewing the videotapes.

Hands-on time was defined as cardiac massage or defibrillation. Each defibrillation was rated as 10 sec of hands-on time. The *first appropriate intervention* was defined as first execution either of a precordial thump, ventilation, cardiac massage, defibrillation, or administration of drugs.

During the first three min after the onset of cardiac arrest behavioural ratings were performed using a predefined checklist adapted from the Leadership Behaviour Description Questionnaire: [4] *Decision what should be done* was rated as present if any utterance occurred, regardless whether correct or followed, on measures to be performed (e.g., "we should defibrillate"); *Decision on how things should be done* was rated as present if any utterance occurred, regardless whether correct or followed, on how to perform a measure (e.g., "the next countershock should be performed with 360 Joule"); *Direction/Command* was rated as present if any utterance occurred, regardless whether correct or followed, prompting a colleague to do something or do it differently (e.g., "you should perform the massage quicker"); *Task assignment* was rated as present if any utterance occurred, regardless whether correct or followed, that assigned a team member to a particular task; *Conflicts* were rated to be present if any argument occurred that was not immediately resolved by a verbal agreement or a decision.

The following parameters were used to assess the *quality of resuscitation measures*: assessment of airway prior to ventilation; chest compressions rate of ≥80/min; compression to ventilation ratio of 15:2; first defibrillation with ≥200 J; three consecutive shocks; escalating energy in subsequent shocks; use of recommended energy in subsequent shocks; correct dose of epinephrine (1 mg). For measures involving cardiac massage, the best performance during the initial 30 sec of cardiac massage was rated.

Statistics

Primary outcome was the amount of hands-on time provided during the first three minutes of the cardiac arrest. Secondary outcomes included timing of events, behavioural ratings and the technical quality of measures of resuscitation. Data were analysed using SPSS (version 15.0), a commercially available statistical software. Cohen's Kappa for inter-rater reliability, Student's t-test, log-rank test, and Fisher's exact test were used as appropriate. A $P < 0.05$ was considered to represent statistical significance.

Results

72 medical students (40 females) and 72 general practitioners (21 females) were allocated to 24 teams composed of three medical students (condition 1) and 24 teams composed of three general practitioners each (condition 2). All teams completed the simulated scenario as intended, and no protocol violations occurred.

As one might expect for items that can be easily recognised, there was no inter-rater disagreement for the timing of events. Inter-rater reliability for the classification of utterances was very good (Cohen's Kappa >0.9; $P < 0.01$); all disagreements were solved by jointly reviewing the video recordings.

At the onset of the cardiac arrest 21/24 general practitioners and 14/24 medical students called for help of their colleagues within 15 sec ($P = 0.002$). The 3 general practitioners not calling for help performed an immediate defibrillation while none of the 10 students not calling for help performed immediate defibrillation or cardiac massage. Two teams of medical students could complete the scenario only with help. Both teams did not perform defibrillation prior to the suggestion of the confederate nurse.

Primary outcomes: Medical students applied significantly less hands-on time during the first three min than general practitioners (52 ± 33 sec vs 105 ± 39 sec; $P < 0.0001$).

Secondary outcomes: Medical students and general practitioners did not differ in the time needed for diagnosing the cardiac arrest (24 ± 14 sec vs 20 ± 10 sec). Medical students performed the first appropriate intervention (77 ± 36 sec vs 45 ± 33 sec; $P = 0.002$), defibrillation (168 ± 78 sec vs 116 ± 46 sec; $P = 0.007$), and cardiac massage (143 ± 63 sec vs 82 ± 67 sec; $P = 0.002$) significantly later than general practitioners (fig. 1). There was, however, no difference in the time until the first injection of epinephrine (213 ± 61 sec vs 219 ± 68 sec; $P = 0.8$). Furthermore, we observed less directive leadership in student teams than in teams of general practitioners (table 1).

Teams of medical students and general practitioners differed significantly ($P = 0.006$) in the kind of the first appropriate intervention: the first appropriate intervention in teams of medical students and general practitioners respectively was ventilation (20/24 and 8/24 respectively), precordial thump (1/24 and 6/24), cardiac massage (2/24 and 6/24), and defibrillation (1/24 and 4/24).

The technical quality of measures of resuscitation is displayed in table 2. Note that medical students performed at least as well as general practitioners in all technical domains, and outperformed general practitioners in some domains.

Figure 1

Survival curve of the timing of the first appropriate intervention (defined as first execution of either precordial thump, ventilation, cardiac massage, defibrillation, or injection of drugs) and the first defibrillation in simulated witnessed cardiac arrest. Time 0 denotes the onset of cardiac arrest. Stud = teams composed of three medical students at the time of their graduation and one confederate nurse; GP = teams composed of three general practitioners and one confederate nurse. There was a statistically significant difference between medical students and general practitioners for both timings (log rank test).

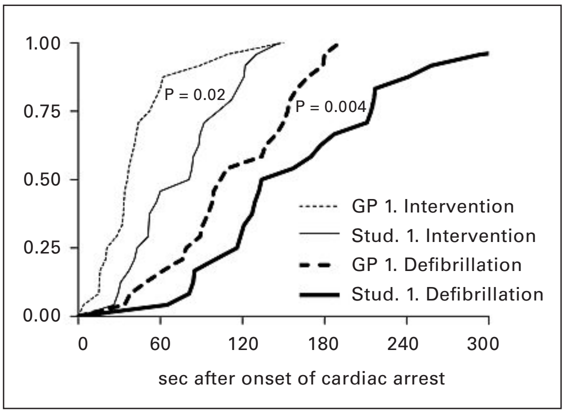

Table 1

Behavioural ratings during cardiopulmonary resuscitation in simulated cardiac arrests.

	Medical students (n = 24)	General practitioners (n = 24)	P
Direction/command	4/24	14/24	0.007
Decision what	23/24	24/24	1.0
Decision how	18/24	17/24	1.0
Task assignment	13/24	13/24	1.0
Conflicts	0/24	2/24	0.49

Table 2

Ratings of the technical performance during cardiopulmonary resuscitation in simulated cardiac arrests.

	Medical students (N = 24)	General practitioners (N = 24)	P
Ventilation performed	23/24	24/24	1.0
Airway check prior to ventilation	3/24	2/24	1.0
Cardiac massage performed	24/24	24/24	1.0
Cardiac compression rate ≥80/min	22/24	14/24	0.017
Synchronisation of massage and ventilation	21/24	20/24	1.0
Energy of 1st Defibrillation ≥200 Joule	23/24	24/24	1.0
Three successive defibrillations	17/24	11/24	0.14
Escalating energy in successive defibrillations	23/24	16/24	0.02
Escalating energy according to guidelines	19/23	11/16	0.036
Epinephrine administered	24/24	24/24	1.0
Correct dose of epinephrine (1 mg)	23/24	24/24	1.0

Discussion

The present study demonstrates that medical students at the time of their graduation are able to diagnose a cardiac arrest as promptly as experienced general practitioners. However, medical students are less likely to call for immediate help, substantially delay evidence-based life-saving measures like defibrillation and provide only half of the resuscitation support provided by experienced general practitioners in the first three minutes.

Shortly after graduation young doctors may have to take over, at least temporarily, the role of the physician responsible in a medical emergency. The current system of post-graduate training in Switzerland cannot guarantee that novices receive additional training prior to their first on-call duties. Thus, the performance in dealing with cardiac arrests in the real world of most, if not all, participants in the first weeks to months of their residency would most likely have mirrored their performance in the present simulator-based study. Delayed defibrillation is associated with lower rates of survival and worse neurological and functional outcomes [5, 6]. Animal data demonstrate a reduced survival rate after frequent or prolonged interruptions of cardiac massage [7–9]. Thus, the combination of delayed defibrillation and reduced hands-on time is of high clinical relevance as the expected impact on mortality and neurological outcome is substantial.

In a witnessed cardiac arrest, immediate defibrillation is a class I recommendation. In keeping with previous studies [5, 10, 11] we observed an unnecessary delay in the time to first defibrillation. The first appropriate intervention in 20/24 teams of medical students was ventilation. This most likely reflects the A-B-C (airway-breathing-circulation) approach taught in cardiopulmonary resuscitation. However, most of the student teams, and some teams composed of general practitioners, continued ventilation well beyond the recommended two rescue breaths, which contributed to the delays in defibrillation and cardiac massage. Thus, our findings suggest that there is a danger for novices (and some others) to "get stuck" in the first steps of an algorithm.

In questionnaire-based assessments of general medical knowledge, medical students and senior physicians tend to achieve very similar scores [12]. Not surprisingly, medical students are outperformed by board-certified specialists and residents in questionnaire-based assessments of more specialised medical knowledge [13, 14]. To the best of our knowledge, this is the first study comparing medical students at the time of their graduation with experienced physicians with regard to their performance during a medical emergency.

A recent study from Geneva demonstrated that both the emergency clerkship training of the medical faculty of Geneva and the emergency programme of the Swiss Army cadets school are effective in improving the medical students' overall knowledge and performance [15]. Our findings indicate that medical students need a special education for the non-technical skills of handling medical emergencies. Future medical education of emergencies should focus on enabling students to 1) translate their knowledge and skills into timely and meaningful action, and, 2) to ensure an adequate team performance by executing appropriate leadership. A recent study stressed the importance of immediate feedback on learning gains [16]. Simulator training, allowing immediate feedback by a video-assisted debriefing, seems to be a promising way of achieving the aforementioned educational goals. However, so far the financial resources of medical schools in Switzerland do no allow the implementation of medical simulation into current curricula except for research purposes.

The knowledge and skills demonstrated by the medical students would have most likely allowed them to pass examinations testing factual recall (e.g., multiple choice questions) or applied knowledge (e.g., oral examination, OSCE). Thus, conventional examinations designed to guarantee a minimum level of competence at the time of graduation are unlikely to predict or prevent a poor performance in one of the most frequent medical emergencies. Indeed, within weeks of their simulation, all medical students participating in the present study successfully passed their final medical exam (Swiss State Exam). Miller introduced the pyramid of competence where the base represents the knowledge components, while the apex represents the performance in real life [17]. As noted by Wass and colleagues, the assessment at the apex of Miller's pyramid with predictive validity of subsequent clinical competencies and a simultaneous educational role is a gold standard yet to be achieved [18]. Medical simulation has the potential to fulfil all these requirements.

Limitations and strengths of our findings relate to the use of a patient simulator. Some authors used video camera recordings or defibrillators capable of event recording to evaluate the performance during CPR [4, 19]. However, such recording equipment is usually made functional during, rather than prior to, resuscitation and therefore misses the initial phase of a cardiac arrest. By contrast, simulation allowed recording objective data from both "patient" and participants right from the start of the cardiac arrest. Further strengths of our study were, 1) that all participants were confronted with perfectly identical conditions; 2) that a comparatively high number of participants could be studied in a controlled and scheduled manner, and 3) that no interventions were necessary in case of a poor performance to protect the patients. Thus, simulation allowed investigating issues that for a variety of medical, practical, and ethical reasons are impossible to investigate in real patients.

The guidelines for CPR have been modified after the completion of the present study which may be regarded as a limitation. However, the main changes in the guidelines relate to technicalities (e.g., compression-to-ventilation ratio of 30:2) and no new behavioural instructions relevant for our research were included. Thus, it is highly unlikely that the new guidelines would substantially affect the observed differences in performance of medical students and physicians.

In conclusion, when confronted with a cardiac arrest, medical students needed significantly more time than general practitioners to translate their skills and knowledge into effective team activity. Future research should focus on how to best prepare medical students to handle medical emergencies. Medical simulation appears to be ideally suited to develop and evaluate such novel ways of medical education.

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References

1 Hunziker S, Tschan F, Semmer NK, et al. Hands-on time during cardiopulmonary resuscitation is affected by the process of teambuilding: a prospective randomised simulator-based trial. BMC Emerg Med. 2009;9:3.
2 Tschan F, Semmer NK, Gautschi D, Hunziker P, Spychiger M, Marsch SU. Leading to recovery: Group performance and coordinative activities in medical emergency driven groups. Human Performance. 2006;19:277–304.
3 Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. The American Heart Association in collaboration with the International Liaison Committee on Resuscitation. Resuscitation. 2000;46:1–448.
4 Cooper S, Wakelam A. Leadership of resuscitation teams: "Lighthouse Leadership". Resuscitation. 1999;42:27–45.
5 Chan PS, Krumholz HM, Nichol G, Nallamothu BK, the American Heart Association National Registry of Cardiopulmonary Resuscitation Investigators. Delayed Time to Defibrillation after In-Hospital Cardiac Arrest. N Engl J Med. 2008;358:9–17.
6 Larsen MP, Eisenberg MS, Cummins RO, Hallstrom AP. Predicting survival from out-of-hospital cardiac arrest: a graphic model. Ann Emerg Med. 1993;22:1652–8.
7 Berg RA, Hilwig RW, Kern KB, Sanders AB, Xavier LC, Ewy GA. Automated external defibrillation versus manual defibrillation for prolonged ventricular fibrillation: lethal delays of chest compressions before and after countershocks. Ann Emerg Med. 2003;42:458–67.
8 Kern KB, Hilwig RW, Berg RA, Sanders AB, Ewy GA. Importance of Continuous Chest Compressions During Cardiopulmonary Resuscitation: Improved Outcome During a Simulated Single Lay-Rescuer Scenario. Circulation. 2002;105:645–9.
9 Yu T, Weil MH, Tang W, et al. Adverse Outcomes of Interrupted Precordial Compression During Automated Defibrillation. Circulation. 2002;106:368–72.
10 Lindekaer AL, Jacobsen J, Andersen G, Laub M, Jensen PF. Treatment of ventricular fibrillation during anaesthesia in an anaesthesia simulator. Acta Anaesthesiol Scand. 1997;41:1280–4.
11 Marsch SC, Muller C, Marquardt K, Conrad G, Tschan F, Hunziker PR. Human factors affect the quality of cardiopulmonary resuscitation in simulated cardiac arrests. Resuscitation. 2004;60:51–6.
12 McQueen AS, Worthy S, Keir MJ. Investigating suspected acute pulmonary embolism – what are hospital clinicians thinking? Clin Radiol. 2008;63:642–50.
13 Freedman KB, Bernstein J. The Adequacy of Medical School Education in Musculoskeletal Medicine. J Bone Joint Surg Am. 1998;80:1421–7.
14 Lubarsky S, Chalk C, Kazitani D, Gagnon R, Charlin B. The Script Concordance Test: a new tool assessing clinical judgement in neurology. Can J Neurol Sci. 2009;36:326–31.
15 Saxer T, Duperrex O, Vermeulen B, Vu Nu V. Emergency medicine training: a prospective, comparative study of an undergraduate clinical clerkship and an army programme. Swiss Med Weekly. 2009;139:423–9.
16 El Saadawi GM, Azevedo R, Castine M, et al. Factors affecting feeling-of-knowing in a medical intelligent tutoring system: the role of immediate feedback as a metacognitive scaffold. Adv Health Sci Educ Theory Pract. 2009;
17 Miller GE. The assessment of clinical skills/competence/performance. Acad Med. 1990;65:S63–7.
18 Wass V, Jones R, Van d, V. Standardized or real patients to test clinical competence? The long case revisited. Med Educ. 2001;35:321–5.
19 Wik L, Kramer-Johansen J, Myklebust H, et al. Quality of Cardiopulmonary Resuscitation During Out-of-Hospital Cardiac Arrest. JAMA. 2005;293:299–304.