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Refreshing medical students' i.v.-cannulation skills: a blinded observer three-arm randomised comparison of mental imagery, part-task trainer simulation, and written instructions

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2
3 1 **Title:** Refreshing medical students' i.v.-cannulation skills: a blinded observer three-arm
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5 2 randomised comparison of mental imagery, part-task trainer simulation, and written
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7 3 instructions
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1
2
3 **25 Abstract (297/300)**
4

5 **26 Introduction:** Intravenous (i.v.) cannulation is a core competence in medicine, but is
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8 **27** considered challenging to learn. This study investigates the effectiveness of three educational
9
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11 **28** strategies used to refresh the i.v. cannulation skills of first-year medical students: mental
12
13 **29** imagery, part-task trainer simulation, and written instructions.

14
15 **30 Materials and Methods:** In this single-centre randomized controlled trial, first-year medical
16
17 **31** students were assigned to one of three different refresher tutorials on i.v. cannulation. Six
18
19 **32** months after their compulsory 4-hr instructor-led i.v.-cannulation course, each student was
20
21 **33** randomized to a 6-min self-learning tutorial: a mental imagery audio-guide session, hands-on
22
23 **34** i.v. cannulation on a part-task trainer, or reading written instructions.

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26 **35** Immediately after the refresher tutorials, trained evaluators who were blinded to the
27
28 **36** randomized group assessed the students' performance. Each evaluator completed a 15-item
29
30 **37** standardized checklist in an Objective Structured Clinical Examination (OSCE) station for i.v.
31
32 **38** cannulation. We performed a descriptive analysis of the data and a one-way ANOVA.
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34
35 **39** Additionally, we investigated the influence of previous i.v. cannulation experience on the total
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37 **40** OSCE score.

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40 **41 Results and Discussion:** On analysing the 309 students' results, we did not find differences in
41
42 **42** the total rating of the performance (in percentage) between the three groups at the OSCE station
43
44 **43** (mental imagery group: $72.0 \pm 17.9\%$; part-task trainer group: $74.4 \pm 15.6\%$; written instructions
45
46 **44** group: $69.9 \pm 16.6\%$, $p=0.158$). Multiple linear regression showed a small but statistically
47
48 **45** significant effect of students' previous i.v. cannulation experience on OSCE performance. With
49
50 **46** the same outcome, written instructions and mental imagery had a better return on effort,
51
52 **47** compared to resource-intensive hands-on training with part-task trainers.

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54
55 **48 Conclusion:** A single, short refresher seems to have a limited effect on i.v.-cannulation skills
56
57 **49** in first-year medical students. Less resource-intensive interventions, such as written
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3 50 instructions or mental imagery, are equally effective compared to hands-on part-task trainer
4
5 51 simulation for refreshing this simple but important skill.
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9
10 53 **Article summary**

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12 54 Strengths and limitations of this study

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15 55 • Randomized adequately powered three-armed study design
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17 56 • Use of mental imagery as a form of non-physical simulation
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19 57 • Single-centre study in first-year medical students, therefore results might not be
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22 58 generalizable
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59 **Introduction:**

60 Patient participation in healthcare education remains an essential part of student training, but
61 practising on real patients raises ethical issues, particularly if it involves training of invasive
62 procedures [1]. Additionally, technological, economic and regulatory changes, not only in
63 anaesthesiology but in most medical specialities, have led to a considerable reduction in
64 bedside teaching opportunities for medical students [2]. This has led to simulation as an
65 educational approach in current competency-based curricula.

66 Simulation designed for the acquisition of technical skills aims to reproduce reality with
67 varying levels of physical fidelity. It offers an alternative approach to learning complex
68 psychomotor and procedural skills, with the opportunity to rehearse them in near-life scenarios
69 in a safe, protected, learner-centred, simulated clinical setting [3].

70 One of the most frequently performed basic medical skills is intravenous (i.v.) cannulation [5,
71 6]. Although this is an invasive skill and challenging to learn [7], proficiency may prevent
72 serious complications, such as infiltration, phlebitis, pain, or severe systemic infection [8-10].
73 Traditionally, medical students were taught this skill through didactic instruction, followed by
74 practice on either an arm part-task trainer or on students or patients [5]. However, these
75 traditional i.v.-cannulation teaching methods are time-consuming, expensive, and the
76 opportunities for practising the technique are often unavailable [11].

77 Recently, mental imagery – a form of non-physical simulation – has been introduced in medical
78 education to teach and maintain skills. Mental imagery is a structured process of mental
79 rehearsal before a procedure [13], and involves visualization, prompted by the use of the
80 senses, and recall, leading to a re-experiencing the initial stimulus at the moment of first
81 exposure. Mental imagery is widely used and recognized as effective in the realms of stroke
82 rehabilitation, cognitive behavioural therapy, high-performance athletics, and professional
83 musicianship [14-16], as a means to improve performance and reduce procedural error.

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3 84 Several studies have investigated mental imagery in postgraduate settings [4, 12, 17, 18], but
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6 85 only one small study used it during i.v. cannulation performed by undergraduate students [19].
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8 86 Mental imagery, due to its simplicity, could facilitate learning and skill maintenance in
9
10 87 undergraduate medical student curricula, and release educators from the physical and temporal
11
12 88 presence of bedside teaching. Furthermore, it may provide an economic alternative to the more
13
14 89 costly low-fidelity simulator model design.

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17 90 This randomized study compared the effectiveness of three non-instructor-led teaching
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19 91 methods— mental imagery, low-fidelity part-task trainer simulation, and traditional written
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21 92 instructions—in refreshing a simple medical psychomotor procedural skill (i.v. cannulation) in
22
23 93 first-year medical students.

24 94 **Methods:**

25 95 *Participants and setting:*

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29 96 All 1st-year medical students from the Medical Faculty of the University of Bern were invited
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31 97 to participate in the study. All participants provided written informed consent to participate,
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33 98 and the Bern Cantonal Ethics Committee (Req-2021-00096, 26.01.2021) waived the need for
34
35 99 ethical approval as no patients were involved. Students who refused to participate or were late
36
37 100 for the Objective Structured Clinical Examination (OSCE) were excluded from the study.
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39 101 Refusal to participate did not affect their formative assessment or any grades arising thereof.
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41 102 All procedures from this investigation met the criteria of the 1964 Declaration of Helsinki and
42
43 103 its amendments [20]. All researchers complied with the Data Protection Act [21] and the Swiss
44
45 104 Law for Human Research [22]. This study was registered in the AEA RCT Registry with the
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47 105 number AEARCTR-0008043. This article adheres to the CONSORT checklist.

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50 106 The compulsory i.v.-cannulation course for 1st-year medical students at the University of Bern
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52 107 took place between late October and mid-December 2020 in the Bernese Interdisciplinary
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54 108 Skills and Simulation Center (BiSS). All students attended two small-group teaching sessions,
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3 109 each two hours long. The first session consisted of practice on an arm part-task trainer (EZ-
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5 110 7010, Erler Zimmer, Germany), and the second consisted of practice on simulated patients
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8 111 using an armband part-task trainer (R16614, Erler Zimmer, Germany), and on fellow medical
9
10 112 students. A short course and its learning outcomes are displayed in Table 1. The physical
11
12 113 practice of the students was individually supervised by trained course tutors (all medical
13
14 114 students in their final years of university) and overseen by experienced intensive care unit
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16
17 115 nurses.

18
19 **Table 1:** Interprofessional i.v.-cannulation Course Outline & Learning Outcomes
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Flipped Classroom (student effort: 1h):	
(1) Preparation with E-Book - The e-book contains the basics that are required for both parts (basics of hygienic hand disinfection, basics of venipuncture), combined with work assignments and study questions).	
<ul style="list-style-type: none"> • Module 1: Hand disinfection: Theory and short MCQ questionnaire • Module 2: Taking blood samples: where and how, pitfalls, tutorial video, 8 min (in German). (https://www.nanoo.tv/link/v/fuzPhkqU, CC BY-NC-ND 4.0) • Module 3: I.v. cannulation: where and how, contraindications, pitfalls, complications, with tutorial video, 9 min (in German). (https://www.nanoo.tv/link/v/vnfRZMCs, CC BY-NC-ND 4.0) 	
Course Part 1 (Duration: 2h)	Course Part 2 (Duration: 2h)
<p>Theory</p> <p>15 minutes i.v.- cannulation 15 minutes taking blood samples</p>	<p>Practice (2h)</p> <p>Practice on model /Practice on peers (voluntary)</p>
<p>Practice (90 min)</p> <p>Practice on model Practice on peers</p>	
Available materials: Positioning aids for the patient's arm, gauze, alcohol swab, tourniquet, i.v cannulas (18G, 20G), cannula dressing, disposal container, gloves	
Tutor concurrent feedback	Tutor concurrent feedback
Further practice: Room and practice model provided for further practice	
Knowledge	<ul style="list-style-type: none"> • List the indications, risks and complications of the procedure; • Name the materials and preparatory steps necessary for the intervention; • Explain the criteria for choosing a suitable location for the procedure; • List and justify the hygiene guidelines for the procedure;

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	<ul style="list-style-type: none"> • Explain important basic rules of the technique; • Describe common principles underlying the different standard operating procedures from institutions.
Skills	<ul style="list-style-type: none"> • Adequately inform normal adults in a standard situation about the indications, risks and procedure of the intervention; • Prepare for the procedure (including providing the necessary materials, labelling tubes, checking the patient's identity, positioning, etc.); • Determine a puncture site for the procedure; • Correctly perform the intervention, following the hygiene guidelines; • Assess own abilities and determine when to call for help in case of problems; • Constructively exchange ideas with other participants.
Attitudes	<ul style="list-style-type: none"> • Assess the patient's fears and apprehensions about the procedure; • Assess how the procedure is experienced from the patient's point of view; • Support a climate of constructive cooperation between different professions; • Reflect on one's function and tasks within an interprofessional team

118

119 *Study design and interventions*

120 We carried out a three-armed, assessor-blinded randomized trial (Figure 1, flowchart). Six
 121 months after the first-year medical students underwent standard i.v.-cannulation training, they
 122 received an invitation explaining the goals of the study. Participants were asked to be on-site
 123 30 minutes before a formative OSCE at the end of the first semester. Upon arrival, all
 124 participants completed a questionnaire to ascertain previous experience in i.v. cannulation,
 125 including attempts and demographics. After that, they were randomly assigned to one of three
 126 groups:

127 1) Group A: a **6 min. mental imagery audio-guided tutorial**: Students listened to a mental
 128 imagery audio recording of an i.v. cannulation procedure, in a dimmed room and using
 129 earphones, while lying down on a lounger. No i.v.-cannulation materials were available.

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3 130 2) Group B: a **6 min. part-task trainer simulation tutorial**: Students practised on a low-fidelity
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5 131 arm part-task trainer like the one they had in their previous course sessions (EZ-7010, Erler
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7 132 Zimmer, Germany). All materials used during the course sessions were available.

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10 133 3) Group C: a **6 min. tutorial with written instructions**: Students revised the i.v.-cannulation
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12 134 steps individually, with the aid of a laminated instruction sheet.

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17 136 *Randomization procedure*

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19 137 Students were allocated according to a 1:1:1 ratio to either the mental imagery group (n=105),
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21 138 the part-task trainer simulation group (n=105) or the written instructions group (n=106) using
22
23 139 block randomization with a fixed block size of 9. The randomization sequence was created
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25 140 through randomization software (www.sealedenvelope.com). The allocation sequence was
26
27 141 concealed from the students and the evaluators, as well as from those involved in the statistical
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29 142 testing of the data.

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35 144 *Construction of the mental imagery audio script and the audio guide*

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37 145 RG, RB and CCG (an anaesthesia-certified nurse), considered specialists in i.v. cannulation,
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39 146 recorded a 45-min online focus group, facilitated by JBE, to develop the mental imagery script.
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41 147 They were asked to describe visual and kinesthetic clues at each step of i.v. cannulation and
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43 148 common pitfalls during i.v. cannulation. The focus group recordings were transcribed and
44
45 149 analysed using iterative content analysis to create the mental practice script. This script was
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47 150 subsequently audio recorded.

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51 151 The guided mental imagery tutorial that was presented to the randomized group of students
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53 152 consisted of a 6-min audio guide with instructions for i.v. cannulation embedded in relaxing
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55 153 breathing exercises. Students were advised to imagine the technique as if they were performing

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3 154 i.v. cannulation themselves. Instructions were delivered at a slow pace and emphasized the
4
5 155 correct technique.
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10 157 *The i.v.-cannulation OSCE assessment*

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12 158 The i.v.-cannulation skill was assessed six months after the initial training, during the 1st year
13
14 159 formative OSCE at the University of Bern's Faculty of Medicine. This OSCE comprised three
15
16 160 different stations assessing 1) i.v.-cannulation skills, 2) basic life support, and 3) history taking.
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18 161 Each station lasted 8 minutes and the students' distribution to one of these stations occurred
19
20 162 randomly.
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24 163 In the 8-min i.v.-cannulation OSCE station, a simulated patient used an i.v.-puncture model
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26 164 strapped to their arm (R16614, Erler Zimmer, Germany) for puncture. The assessment was
27
28 165 conducted by trained evaluators using a 15-item OSCE checklist in use at the University of
29
30 166 Bern, which was tested for internal consistency. This setting and the structure of the checklist
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32 167 ensured that procedural flow, psychomotor skills as well as communicative aspects of the
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34 168 students' i.v.-cannulation performance could be assessed. Evaluators were all experienced
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36 169 anaesthesia nurses blinded to the students' group rehearsal assignment. All evaluators took part
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38 170 in a 30-min training session on completing the checklist.
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44 172 *Statistical analysis*

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46 173 Our primary outcome was the total score in percentage of the OSCE assessment for the i.v.-
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48 174 cannulation station. Additionally, the influence of previous i.v.cannulation experience on the
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50 175 total OSCE score was examined.
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53 176 We performed a multi-arm sample size calculation, aiming to demonstrate superiority of one
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55 177 of the educational strategies using an *a priori* power analysis with G*Power V.3.1.[23]
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58 178 Assuming an effect size ($f=0.305$) for a one-way analysis of variance with three groups
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3 179 ($\alpha=0.01$, $1-\beta=0.80$), we found that the minimum required sample size for three groups was
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5 180 $n=156$. To compensate for 20% of non-responders, we aimed for 180 participants.
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8 181 Statistical analysis was performed using SPSS 27 (IBM Corp, Armonk, NY, USA). Categorical
9
10 182 variables were described as absolute (n) and relative frequencies (%). Continuous variables
11
12 183 were described using mean and standard deviation. In order to control for possible confounding
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14 184 effects, interdependence of categorical variables with the three groups was tested using a Chi-
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16 185 squared test for contingency tables, and one-way ANOVAs were used to test possible
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18 186 differences in the means of continuous variables between the three groups. For reliability
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20 187 testing of the checklist, internal consistency was evaluated with Chronbach's alpha.
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23 188 A one-way analysis of variance (ANOVA) was conducted to compare the means of the total
24
25 189 OSCE score in percentages of the three groups. The number of previous attempts at i.v.
26
27 190 cannulation using part-task trainer simulation and the number of previous attempts at live i.v.
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29 191 cannulation served as predictors in a multiple linear regression with the total score in
30
31 192 percentage as dependent variable. An a priori probability of less than 0.05 was considered to
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33 193 be statistically significant.
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40 195 *Patient and Public Involvement*

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42 196 No patient involved.
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46 47 198 **Results**

48
49 199 Three hundred and sixteen students were invited to participate in the study. After excluding
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51 200 students who did not attend the OSCE or arrived late, 309 students were enrolled (participation
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53 201 rate of 97.8%). The participants' characteristics did not differ between the three groups (Table
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55 202 2). Overall, the items in the checklist showed an internal consistency of $\alpha= 0.691$, which is
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57 203 considered acceptable [24].
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204 **Table 2:** Participants' characteristics

	Total	Mental	Part-Task	Written	p-value
	(n=309)	Imagery	Trainer	Instructions	
		(n=104)	(n=100)	(n=105)	
Age, years (mean±SD)	21.3±1.9	21.1±1.9	21.2±1.7	21.6±2.2	0.500
Female sex, n (%)	189 (61.2)	64 (62.1)	69 (68.3)	56 (53.3)	0.085*
German mother tongue, n (%)	282 (91.0)	92 (89.3)	92 (91.1)	98 (92.5)	0.545*
No previous experience in healthcare, n (%)	301 (97.4)	101 (98.1)	96 (95.0)	104 (98.1)	0.563*
Previous attempts at i.v.-cannulation in part-task trainer simulation, n (mean±SD)	3.0±1.9	3.1±1.9	2.9±1.9	3.0±1.9	0.693
Previous attempts at live i.v.cannulation, n (mean±SD)	3.2±8.0	2.3±1.9	3.8±9.0	3.6±10.4	0.372

205 *Chi-square

206
207 There was no statistically significant difference between groups in the one-way ANOVA on
208 our primary outcome the students' overall i.v.-cannulation performance rating: mental imagery
209 scored 72.0±17.9%, part-task trainer simulation scored 74.4±15.6%, and written instructions
210 scored 69.9±16.6% ($F_{2,306} = 1.856, p = 0.158$).

211 Stepwise multiple linear regression showed that i.v.-cannulation experience during part-task
212 trainer simulation had a significant but small effect on the OSCE performance (R^2
213 = 0.015, $p = 0.031$). Students reported the number of previous attempts at cannulation as
214 6.5±8.5, without differences between the three groups ($p=0.224$). The live i.v.-cannulation
215 experience showed no contribution to the OSCE performance.

216 Discussion

217 Our study shows that the performance of i.v. cannulation, assessed at an objective, structured
218 skills exam, did not differ after three different refresher tutorials (mental imagery, part-task
219 trainer simulation, and written instructions).

220 Our results differ from those of several randomised controlled trials on mental imagery in
221 postgraduate education. Studies that involved surgical trainees' "warming up" with mental
222 imagery [17, 18] described significantly improved performance with a warm-up before
223 laparoscopic surgery. However, when considering the effects of warm-up on the different
224 aspects of psychomotor performance, Paschold et al. [25] found that these were affected by the
225 nature of the warm-up, the type of surgery, and the expertise of the surgeon. This suggests that
226 optimal warm-up strategies are task- and procedure-specific and may change with varying
227 expertise [4], consequently yielding conflicting results.

228 Use of mental imagery in anaesthesia studies also showed conflicting findings. A 2016 study
229 reported improved fiberoptic intubation skills after a 5-minute mental imagery warm-up on a
230 virtual reality bronchoscopy simulator when compared with a control group [26]. In contrast,
231 anaesthetists practicing mental imagery did not manage crises better during simulation [27].
232 The reasons proposed by the study authors for the negative results were the nature of the task,
233 the limited "dose" effect (20 min vs. the 30–90 min reported in successful interventions), and
234 the number reduced of cues in the mental script.

235 More recently, comparable effects of mental imagery and low-fidelity simulation were
236 described in anaesthesiology residents learning to administer epidural anaesthesia [28]. Our
237 study results align with the latter, as all three "warm-up" methods resulted in similar student
238 performance in an objective, structured skills exam.

239 It is of more interest to compare our results with the study by Sanders et al. [19]. They also did
240 not find a significant difference in medical students' venipuncture performance with or without

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3 241 mental imagery. But they did find a significant difference in student performance between part-
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5 242 task trainer simulation and a control. Those authors assessed their students immediately after
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7 243 their training session, while our assessment occurred following the refresher, at 6 months after
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9 244 the initial training. Thus the two studies might not be readily comparable.

10 245 The number of previous i.v.-cannulation part-task trainer simulation attempts had a small but
11
12 246 significant effect on the OSCE performance. Students in our study performed, on average, more
13
14 247 than six attempts at i.v. cannulation in the 6 months before their first-year OSCE. This number
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16 248 is considered as the number of attempts necessary to achieve a plateau level of the learning
17
18 249 curve for this procedure [7, 29]. That might partly explain why the three different refresher
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20 250 strategies resulted in comparable results. As our study participants reached the critical mass of
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22 251 medical students who had already acquired the necessary skills in i.v.-cannulation before the
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24 252 study took place, an improvement might be hard to detect, and our students probably did not
25
26 253 necessarily profit from these refreshers. That might explain the puzzling finding in our study
27
28 254 that the written instructions group was just as effective as the other two interventions, and
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30 255 questions the need for such a refresher shortly before an OSCE at all.

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33 256 Although we did not formally assess the cost of our three interventions, it seems obvious that
34
35 257 written instructions and mental imagery are far more economical than the purchase and
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37 258 maintenance of a low-fidelity part-task arm, including the instructor's salary and time spent
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39 259 teaching). This cost-effectiveness argument needs to be further investigated in a properly
40
41 260 performed cost-effectiveness analysis.

42
43 261 Our study has several other limitations. It assessed the effectiveness of different refresher
44
45 262 techniques for i.v.-cannulation skills, but its successful transfer to clinical practice could not
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47 263 be ascertained. We assume that our results can be applied to related techniques which require
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49 264 venipuncture, like taking blood samples, but despite our robust design, our results may not be
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51 265 generalizable to other cohorts. Additionally, due to the post-test methodology of the study, no
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3 266 conclusion can be taken regarding the student's performance of i.v. cannulation before the
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5 267 intervention. Finally, it is possible that the 6-minute intervention was simply too short to detect
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8 268 a difference in the teaching strategy and its effect on the performance of the skill.

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10 269 In summary, these results suggest that all interventions were similarly successful at refreshing
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12 270 i.v.-cannulation procedures in undergraduate medical students.

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15 271 **Conclusions:**

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17 272 Medical schools currently seek to offer more efficient, cost-effective and innovative methods
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19 273 to enhance learning. Our study comparing three 6-minute refresher strategies, indicates that
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21 274 part-task trainer simulation is not superior to mental imagery and written instructions for
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23 275 refreshing i.v.-cannulation skills in first-year medical students. Both mental imagery and
24
25 276 written instructions have a far better effort-return ratio than resource-intensive hands-on
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27 277 training with part-task trainer simulation. Mental imagery and written instructions cannot
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29 278 completely replace physical clinical skills training in i.v. cannulation, but may effectively
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31 279 supplement it, similar to other fields involving complex psychomotor skill learning.
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3 **280 Declarations**
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5 **281 Ethics approval and consent to participate:** All participants provided written informed
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7
8 **282** consent to participate and the Bern Cantonal Ethics Committee (Req-2021-00096, 26.01.2021)
9
10 **283** waived the need for ethical approval as no patients were involved.

11
12 **284 Consent for publication:** Not applicable
13

14
15 **285 Availability of data and materials:** The data generated and analysed during the current study
16
17 **286** are available in the manuscript and the Supplemental Digital Content. Datasets containing
18
19 **287** student information are available after anonymization from the corresponding author on
20
21 **288** reasonable request. More information on the study can be found at
22
23 **289** <https://doi.org/10.1257/rct.8043-1.0>.
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26 **290**

27
28 **291 Competing interests:** RG is the Director of Training and Education of the European
29
30 **292** Resuscitation Council, the Task Force Chair Education, Implementation, and Team of ILCOR,
31
32 **293** and a member of the Direction of the MME Program of the University of Bern. The remaining
33
34 **294** authors report no declarations of interest.
35
36

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38
39 **296** and Pain Medicine, Inselspital, Bern University Hospital, University of Bern, Bern,
40
41 **297** Switzerland
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45 **298**

46
47 **299 Author contributions:**
48

49 **300** JBE wrote the outline and performed the data collection, demographic statistical analysis and
50
51 **301** interpretation of the data.
52

53 **302** RB and MB contributed to the outline, performed the data collection, and helped in data
54
55 **303** interpretation and the writing process.
56
57

58 **304** DS performed the bivariate statistical analysis and helped interpret the data.
59
60

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3 305 RG initiated the study, supervised the creation and adaptation of the outline, and critically
4
5 306 reviewed the manuscript.

6
7
8 307 CB supervised the creation and adaptation of the outline, performed data collection and helped
9
10 308 in data interpretation and the writing process.

11
12 309 All of the authors have read and approved the final version of the manuscript.

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15 310

16
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30
31 318 proofreading of the manuscript.

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340 **References:**

- 341 1. Santen SA, Hemphill RR, McDonald MF, Jo CO. Patients' willingness to allow
342 residents to learn to practice medical procedures. *Acad Med.* 2004;79(2):144-7.
- 343 2. Berger-Estilita JM, Greif R, Berendonk C, Stricker D, Schnabel KP. Simulated
344 patient-based teaching of medical students improves pre-anaesthetic assessment: A rater-
345 blinded randomised controlled trial. *Eur J Anaesthesiol.* 2020;37(5):387-93.
- 346 3. Cook DA, Brydges R, Zendejas B, Hamstra SJ, Hatala R. Mastery learning for health
347 professionals using technology-enhanced simulation: a systematic review and meta-analysis.
348 *Acad Med.* 2013;88(8):1178-86.
- 349 4. Weller JM. Improving procedural performance through warm-up and mental imagery.
350 *Br J Anaesth.* 2016;116(3):315-7.
- 351 5. McWilliams LA, Malecha A. Comparing Intravenous Insertion Instructional Methods
352 with Haptic Simulators. *Nurs Res Pract.* 2017;2017:4685157.
- 353 6. Lund F, Schultz JH, Maatouk I, Krautter M, Moltner A, Werner A, et al.
354 Effectiveness of IV cannulation skills laboratory training and its transfer into clinical
355 practice: a randomized, controlled trial. *PLoS One.* 2012;7(3):e32831.
- 356 7. Stolz LA, Cappa AR, Minckler MR, Stolz U, Wyatt RG, Binger CW, et al.
357 Prospective evaluation of the learning curve for ultrasound-guided peripheral intravenous
358 catheter placement. *J Vasc Access.* 2016;17(4):366-70.
- 359 8. Eggimann P, Sax H, Pittet D. Catheter-related infections. *Microbes Infect.*
360 2004;6(11):1033-42.
- 361 9. Guembe M, Perez-Granda MJ, Capdevila JA, Barberan J, Pinilla B, Martin-Rabadan
362 P, et al. Nationwide study on peripheral-venous-catheter-associated-bloodstream infections in
363 internal medicine departments. *J Hosp Infect.* 2017;97(3):260-6.
- 364 10. Ray-Barruel G, Xu H, Marsh N, Cooke M, Rickard CM. Effectiveness of insertion
365 and maintenance bundles in preventing peripheral intravenous catheter-related complications
366 and bloodstream infection in hospital patients: A systematic review. *Infect Dis Health.*
367 2019;24(3):152-68.
- 368 11. Jung EY, Park DK, Lee YH, Jo HS, Lim YS, Park RW. Evaluation of practical
369 exercises using an intravenous simulator incorporating virtual reality and haptics device
370 technologies. *Nurse Educ Today.* 2012;32(4):458-63.
- 371 12. Moran-Atkin E, Abdalla G, Chen G, Magnuson TH, Lidor AO, Schweitzer MA, et al.
372 Preoperative warm-up the key to improved resident technique: a randomized study. *Surg
373 Endosc.* 2015;29(5):1057-63.
- 374 13. Weller JM, Castanelli DJ, Chen Y, Jolly B. Making robust assessments of specialist
375 trainees' workplace performance. *Br J Anaesth.* 2017;118(2):207-14.
- 376 14. Rogers RG. Mental practice and acquisition of motor skills: examples from sports
377 training and surgical education. *Obstet Gynecol Clin North Am.* 2006;33(2):297-304, ix.
- 378 15. Cocks M, Moulton CA, Luu S, Cil T. What surgeons can learn from athletes: mental
379 practice in sports and surgery. *J Surg Educ.* 2014;71(2):262-9.
- 380 16. Martin J. Mental preparation for the 2014 Winter Paralympic Games. *Clin J Sport
381 Med.* 2012;22(1):70-3.
- 382 17. Abdalla G, Moran-Atkin E, Chen G, Schweitzer MA, Magnuson TH, Steele KE. The
383 effect of warm-up on surgical performance: a systematic review. *Surg Endosc.*
384 2015;29(6):1259-69.
- 385 18. Makhdom AM, Almaawi A, Tanzer D, Tanzer M. Does warming up improve surgical
386 outcome in total hip arthroplasty? *Eur J Orthop Surg Traumatol.* 2015;25(8):1265-9.
- 387 19. Sanders CW, Sadoski M, Wasserman RM, Wiprud R, English M, Bramson R.
388 Comparing the Effects of Physical Practice and Mental Imagery Rehearsal on Learning Basic

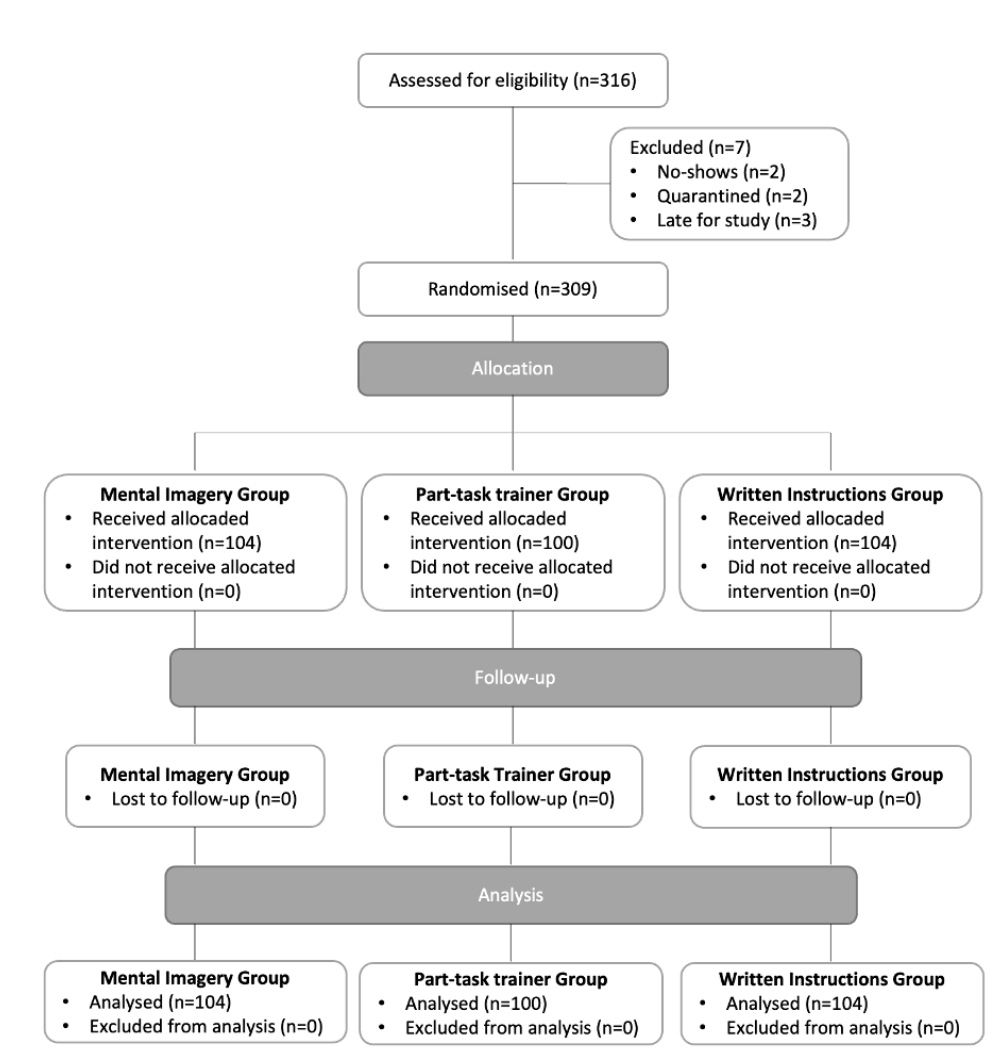
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2
3 389 Venipuncture by Medical Students. *Imagination, Cognition and Personality*. 2007;27(2):117-
4 390 27.
- 5 391 20. WMA WMA. WMA declaration of Helsinki: Ethical principles for medical research
6 392 involving human subjects. 2013.
- 7 393 21. gov.uk. Data Protection Act UK2018 [Available from: gov.uk.
- 8 394 22. Verordnung über klinische Versuche in der Humanforschung Switzerland: Der
9 395 Schweizerische Bundesrat 2013 [cited Der Schweizerische Bundesrat. Available from:
10 396 <https://www.admin.ch/opc/de/official-compilation/2013/3407.pdf>.
- 11 397 23. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power
12 398 analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*.
13 399 2007;39(2):175-91.
- 14 400 24. Taber KS. The Use of Cronbach's Alpha When Developing and Reporting Research
15 401 Instruments in Science Education. *Research in Science Education*. 2018;48(6):1273-96.
- 16 402 25. Paschold M, Huber T, Kauff DW, Buchheim K, Lang H, Kneist W. Preconditioning
17 403 in laparoscopic surgery--results of a virtual reality pilot study. *Langenbecks Arch Surg*.
18 404 2014;399(7):889-95.
- 19 405 26. Samuelson ST, Burnett G, Sim AJ, Hofer I, Weinberg AD, Goldberg A, et al.
20 406 Simulation as a set-up for technical proficiency: can a virtual warm-up improve live fibre-
21 407 optic intubation? *Br J Anaesth*. 2016;116(3):398-404.
- 22 408 27. Hayter MA, Bould MD, Afsari M, Riem N, Chiu M, Boet S. Does warm-up using
23 409 mental practice improve crisis resource management performance? A simulation study. *Br J*
24 410 *Anaesth*. 2013;110(2):299-304.
- 25 411 28. Lim G, Krohner RG, Metro DG, Rosario BL, Jeong JH, Sakai T. Low-Fidelity Haptic
26 412 Simulation Versus Mental Imagery Training for Epidural Anesthesia Technical Achievement
27 413 in Novice Anesthesiology Residents: A Randomized Comparative Study. *Anesth Analg*.
28 414 2016;122(5):1516-23.
- 29 415 29. Loukas C, Nikiteas N, Kanakis M, Moutsatsos A, Leandros E, Georgiou E. A virtual
30 416 reality simulation curriculum for intravenous cannulation training. *Acad Emerg Med*.
31 417 2010;17(10):1142-5.
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419 **Figures:**

420 **Figure 1:** Study Flowchart

For peer review only



Study Flowchart

159x167mm (150 x 150 DPI)



CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	5
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	6
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	5
	4b	Settings and locations where the data were collected	5-6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	5-7
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	8-9
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	8
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	7
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	7
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	7
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	7
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	7

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	6
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	8-9
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	9
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	Fig. 1
	13b	For each group, losses and exclusions after randomisation, together with reasons	Fig. 1
Recruitment	14a	Dates defining the periods of recruitment and follow-up	N/A
	14b	Why the trial ended or was stopped	N/A
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Table 1
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	9
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	9
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	N/A
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	N/A
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	11
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	11
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	10-11
Other information			
Registration	23	Registration number and name of trial registry	5
Protocol	24	Where the full trial protocol can be accessed, if available	13
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	13

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

BMJ Open

Refreshing medical students' i.v.-cannulation skills: a blinded observer three-arm randomised comparison of mental imagery, part-task trainer simulation, and written instructions

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2021-057201.R1
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Date Submitted by the Author:	22-Feb-2022
Complete List of Authors:	Berger-Estilita, Joana; University of Bern, Department of Anaesthesiology and Pain Medicine; University of Porto Blülle, Rafael; University of Bern, Department of Anaesthesiology and Pain Medicine Stricker, Daniel ; University of Berne Institute for Medical Education Balmer, Mathias; University of Bern, Bernese Institute of Primary Healthcare Greif, Robert ; Inselspital Universitätsspital Bern, Anaesthesiology and Pain Therapy Berendonk, Christoph; Universität Bern Institut für Medizinische Lehre
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Medical education and training, Anaesthesia
Keywords:	Adult anaesthesia < ANAESTHETICS, EDUCATION & TRAINING (see Medical Education & Training), MEDICAL EDUCATION & TRAINING

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3 1 **Title:** Refreshing medical students' i.v.-cannulation skills: a blinded observer three-arm
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5 2 randomised comparison of mental imagery, part-task trainer simulation, and written
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7 3 instructions
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49 21 **Keywords:** mental imagery, simulation, venous cannulation, medical education, anaesthesia
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52 22 **Trial registration:** AEARCTR-0008043
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56 24 **Word count:** Abstract 296 words, manuscript 2542 words
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3 **25 Abstract (297/300)**
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5 **26 Introduction:** Intravenous (i.v.) cannulation is a core competence in medicine, but is
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8 **27** considered challenging to learn. This study investigates the effectiveness of three educational
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11 **28** strategies used to refresh the i.v. cannulation skills of first-year medical students: mental
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13 **29** imagery, part-task trainer simulation, and written instructions.

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15 **30 Materials and Methods:** In this single-centre randomized controlled trial, first-year medical
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17 **31** students were assigned to one of three different refresher tutorials on i.v. cannulation. Six
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19 **32** months after their compulsory 4-hr instructor-led i.v.-cannulation course, each student was
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21 **33** randomized to a 6-min self-learning tutorial: a mental imagery audio-guide session, hands-on
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23 **34** i.v. cannulation on a part-task trainer, or reading written instructions.

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26 **35** Immediately after the refresher tutorials, trained evaluators who were blinded to the
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28 **36** randomized group assessed the students' performance. Each evaluator completed a 15-item
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30 **37** standardized checklist in an Objective Structured Clinical Examination (OSCE) station for i.v.
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32 **38** cannulation. We performed a descriptive analysis of the data and a one-way analysis of
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34 **39** variance. Additionally, we investigated the influence of previous i.v. cannulation experience
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36 **40** on the total OSCE score.

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41 **41 Results and Discussion:** On analysing the 309 students' results, we did not find differences in
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43 **42** the total rating of the performance (in percentage) between the three groups at the OSCE station
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45 **43** (mental imagery group: 72.0±17.9%; part-task trainer group: 74.4±15.6%; written instructions
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47 **44** group: 69.9±16.6%, p=0.158). Multiple linear regression showed a small but statistically
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49 **45** significant effect of students' previous i.v. cannulation experience on OSCE performance. With
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51 **46** the same outcome, written instructions and mental imagery had a better return on effort,
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53 **47** compared to resource-intensive hands-on training with part-task trainers.

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56 **48 Conclusion:** A single, short refresher seems to have a limited effect on i.v.-cannulation skills
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58 **49** in first-year medical students. Less resource-intensive interventions, such as written
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3 50 instructions or mental imagery, are effective compared to hands-on part-task trainer simulation
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5 51 for refreshing this simple but important skill.
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10 53 **Article summary**

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12 54 Strengths and limitations of this study

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15 55 • Randomized adequately powered three-armed study design
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17 56 • Use of mental imagery as a form of non-physical simulation
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19 57 • Single-centre study in first-year medical students, therefore results might not be
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59 **Introduction:**

60 Patient participation in healthcare education remains an essential part of student training, but
61 practising on real patients raises ethical issues, particularly if it involves training of invasive
62 procedures [1]. Additionally, technological, economic and regulatory changes, not only in
63 anaesthesiology but in most medical specialities, have led to a considerable reduction in
64 bedside teaching opportunities for medical students [2]. This has led to simulation as an
65 educational approach in current competency-based curricula.

66 Simulation designed for the acquisition of technical skills aims to reproduce reality with
67 varying levels of physical fidelity. It offers an alternative approach to learning complex
68 psychomotor and procedural skills, with the opportunity to rehearse them in near-life scenarios
69 in a safe, protected, learner-centred, simulated clinical setting [3].

70 One of the most frequently performed basic medical skills is intravenous (i.v.) cannulation [
71 4, 5]. Although this is an invasive skill and challenging to learn [6], proficiency may prevent
72 serious complications, such as infiltration, phlebitis, pain, or severe systemic infection [7-9].
73 Traditionally, medical students were taught this skill through didactic instruction, followed by
74 practice on either an arm part-task trainer or on students or patients [4]. However, these
75 traditional i.v.-cannulation teaching methods are time-consuming, expensive, and the
76 opportunities for practising the technique are often unavailable [10].

77 Recently, mental imagery – a form of non-physical simulation – has been introduced in medical
78 education to teach and maintain skills [11]. Mental imagery is a structured process of mental
79 rehearsal before a procedure [12], and involves visualization, prompted by the use of the
80 senses, and recall, leading to a re-experiencing the initial stimulus at the moment of first
81 exposure. Mental imagery is widely used and recognized as effective in the realms of stroke
82 rehabilitation, cognitive behavioural therapy, high-performance athletics, and professional
83 musicianship [13-15], as a means to improve performance and reduce procedural error.

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3 84 Several studies have investigated mental imagery in postgraduate settings [16-19], but only
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6 85 one small study used it during i.v. cannulation performed by undergraduate students [20].
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8 86 Mental imagery, due to its simplicity, could facilitate learning and skill maintenance in
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10 87 undergraduate medical student curricula, and release educators from the physical and temporal
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12 88 presence of bedside teaching. Furthermore, it may provide an economic alternative to the more
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15 89 costly low-fidelity simulator model design.

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17 90 This randomized study compared the effectiveness of three non-instructor-led teaching
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19 91 methods— mental imagery, low-fidelity part-task trainer simulation, and traditional written
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21 92 instructions—in refreshing a simple medical psychomotor procedural skill (i.v. cannulation) in
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24 93 first-year medical students.

25 26 94 **Methods:**

27 28 95 *Participants and setting:*

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31 96 All 1st-year medical students from the Medical Faculty of the University of Bern were invited
32
33 97 to participate in the study. All participants provided written informed consent to participate,
34
35 98 and the Bern Cantonal Ethics Committee (Req-2021-00096, 26.01.2021) waived the need for
36
37 99 ethical approval as no patients were involved. Students who refused to participate or were late
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39
40 100 for the Objective Structured Clinical Examination (OSCE) were excluded from the study.
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42 101 Refusal to participate did not affect their formative assessment or any grades arising thereof.
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44 102 All procedures from this investigation met the criteria of the 1964 Declaration of Helsinki and
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46 103 its amendments [21]. All researchers complied with the Data Protection Act [22] and the Swiss
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48
49 104 Law for Human Research [23]. This study was registered in the AEA RCT Registry with the
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52 105 number AEARCTR-0008043[24]. This article adheres to the CONSORT checklist.
53
54 106 The compulsory i.v.-cannulation course for 1st-year medical students at the University of Bern
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56 107 took place between late October and mid-December 2020 in the Bernese Interdisciplinary
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58
59 108 Skills and Simulation Center (BiSS). All students attended two small-group teaching sessions,
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3 109 each two hours long. The first session consisted of practice on an arm part-task trainer (EZ-
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5 110 7010, Erler Zimmer, Germany), and the second consisted of practice on simulated patients
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8 111 using an armband part-task trainer (R16614, Erler Zimmer, Germany), and on fellow medical
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10 112 students. A short course and its learning outcomes are displayed in Table 1. The physical
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12 113 practice of the students was individually supervised by trained course tutors (all medical
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14 114 students in their final years of university) and overseen by experienced intensive care unit
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17 115 nurses.

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19 **Table 1:** Interprofessional i.v.-cannulation Course Outline & Learning Outcomes
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Flipped Classroom (student effort: 1h):	
(1) Preparation with E-Book - The e-book contains the basics that are required for both parts (basics of hygienic hand disinfection, basics of venipuncture), combined with work assignments and study questions).	
<ul style="list-style-type: none"> • Module 1: Hand disinfection: Theory and short MCQ questionnaire • Module 2: Taking blood samples: where and how, pitfalls, tutorial video, 8 min (in German). (https://www.nanoo.tv/link/v/fuzPhkqU, CC BY-NC-ND 4.0) • Module 3: I.v. cannulation: where and how, contraindications, pitfalls, complications, with tutorial video, 9 min (in German). (https://www.nanoo.tv/link/v/vnfrZMCs, CC BY-NC-ND 4.0) 	
Course Part 1 (Duration: 2h)	Course Part 2 (Duration: 2h)
<p>Theory</p> <p>15 minutes i.v.- cannulation 15 minutes taking blood samples</p>	<p>Practice (2h)</p> <p>Practice on model /Practice on peers (voluntary)</p>
<p>Practice (90 min)</p> <p>Practice on model Practice on peers</p>	
Available materials: Positioning aids for the patient's arm, gauze, alcohol swab, tourniquet, i.v cannulas (18G, 20G), cannula dressing, disposal container, gloves	
Tutor concurrent feedback	Tutor concurrent feedback
Further practice: Room and practice model provided for further practice	

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Knowledge	<ul style="list-style-type: none"> • List the indications, risks and complications of the procedure; • Name the materials and preparatory steps necessary for the intervention; • Explain the criteria for choosing a suitable location for the procedure; • List and justify the hygiene guidelines for the procedure;
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	<ul style="list-style-type: none"> • Explain important basic rules of the technique; • Describe common principles underlying the different institutional standards;
Skills	<ul style="list-style-type: none"> • Adequately inform normal adults in a standard situation about the indications, risks and procedure of the intervention; • Prepare for the procedure (including providing the necessary materials, labelling tubes, checking the patient's identity, positioning, etc.); • Determine a puncture site for the procedure; • Correctly perform the intervention, following the hygiene guidelines; • Assess own abilities and determine when to call for help in case of problems; • Constructively exchange ideas with other participants.
Attitudes	<ul style="list-style-type: none"> • Assess the patient's fears and apprehensions about the procedure; • Assess how the procedure is experienced from the patient's point of view; • Support a climate of constructive cooperation between different professions; • Reflect on one's function and tasks within an interprofessional team

118

119 *Study design and interventions*

120 We carried out a three-armed, assessor-blinded randomized trial (Figure 1, flowchart). Six
 121 months after the first-year medical students underwent standard i.v.-cannulation training, they
 122 received an invitation explaining the goals of the study. Students were unaware of the specific
 123 skill or interventions of the study. Participants were asked to be on-site 30 minutes before a
 124 formative OSCE at the end of the first semester. Upon arrival, all participants completed a
 125 questionnaire to ascertain previous experience in i.v. cannulation, including attempts and
 126 demographics. After that, they were randomly assigned to one of three groups:

127 1) Group A: a **6 min. mental imagery audio-guided tutorial**: Students listened to a mental
 128 imagery audio recording of an i.v. cannulation procedure, in a dimmed room and using
 129 earphones, while lying down on a lounger. No i.v.-cannulation materials were available.

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3 130 2) Group B: a **6 min. part-task trainer simulation tutorial**: Students practised on a low-fidelity
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5 131 arm part-task trainer like the one they had in their previous course sessions (EZ-7010, Erler
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7 132 Zimmer, Germany). All materials used during the course sessions were available.

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10 133 3) Group C: a **6 min. tutorial with written instructions**: Students revised the i.v.-cannulation
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12 134 steps individually, with the aid of a laminated instruction sheet.

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17 136 *Randomization procedure*

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19 137 Students were allocated according to a 1:1:1 ratio to either the mental imagery group (n=105),
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21 138 the part-task trainer simulation group (n=105) or the written instructions group (n=106) using
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23 139 block randomization with a fixed block size of 9. The randomization sequence was created
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25 140 through randomization software (www.sealedenvelope.com). The allocation sequence was
26
27 141 concealed from the students and the evaluators, as well as from those involved in the statistical
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29 142 testing of the data.

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35 144 *Construction of the mental imagery audio script and the audio guide*

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37 145 RG, RB and CCG (an anaesthesia-certified nurse), considered specialists in i.v. cannulation,
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39 146 recorded a 45-min online mini-focus group [25], facilitated by JBE, to develop the mental
40
41 147 imagery script. They were asked to describe visual and kinesthetic clues at each step of i.v.
42
43 148 cannulation and common pitfalls during i.v. cannulation. The focus group recordings were
44
45 149 transcribed and analysed using iterative content analysis to create the mental practice script.
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47 150 This script was subsequently audio recorded and piloted amongst all authors and one additional
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49 151 colleague, proficient in hypnosis (FL, in acknowledgements).

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52 152 The guided mental imagery tutorial that was presented to the randomized group of students
53
54 153 consisted of a 6-min audio guide with instructions for i.v. cannulation embedded in relaxing
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56 154 breathing exercises. Students were advised to imagine the technique as if they were performing

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3 155 i.v. cannulation themselves. Instructions were delivered at a slow pace (*circa* 100 spoken
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5 156 words/minute) and emphasized the correct technique.
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10 158 *The i.v.-cannulation OSCE assessment*
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12 159 The i.v.-cannulation skill was assessed six months after the initial training, during the 1st year
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14 160 formative OSCE at the University of Bern's Faculty of Medicine. This OSCE comprised three
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16 161 different stations assessing 1) i.v.-cannulation skills, 2) basic life support, and 3) history taking.
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18 162 Each station lasted 8 minutes and the students' distribution to one of these stations occurred
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20 163 randomly. As this was a formative OSCE, students were aware of the skills being tested.
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22 164 Students were not able to communicate with each other during the examination.
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26 165 In the 8-min i.v.-cannulation OSCE station, a simulated patient used an i.v.-puncture model
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28 166 strapped to their arm (R16614, Erler Zimmer, Germany) for puncture. The assessment was
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30 167 conducted by trained evaluators using a 15-item OSCE checklist in use at the University of
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32 168 Bern, which was tested for internal consistency. This setting and the structure of the checklist
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34 169 ensured that procedural flow, psychomotor skills (a total of two cannulation attempts were
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36 170 allowed), as well as communicative aspects of the students' i.v.-cannulation performance could
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38 171 be assessed. All six evaluators were all experienced anaesthesia study nurses (see
39
40 172 Acknowledgements) blinded to the students' group rehearsal assignment. All evaluators took
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42 173 part in a 30-min training session in the use of the rating scales and on completing the checklist.
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44 174 We considered the assessor effect to be negligible, since the overall performance of the three
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46 175 intervention groups was of interest, and candidates were randomly assigned to the three
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48 176 intervention groups.
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3 180 *Statistical analysis*
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5 181 Our primary outcome was the total score in percentage of the 15-item OSCE assessment for
6
7 182 the i.v.-cannulation station. Additionally, the influence of previous i.v.cannulation experience
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9 183 on the total OSCE score was examined.

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12 184 We performed a multi-arm sample size calculation, aiming to demonstrate superiority of one
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14 185 of the educational strategies using an *a priori* power analysis with G*Power V.3.1. [(26)]

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17 186 Assuming an effect size ($f=0.305$) for a one-way analysis of variance with three groups
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19 187 ($\alpha=0.01$, $1-\beta=0.80$), we found that the minimum required sample size for three groups was
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21 188 $n=156$ (52 per group). To compensate for 20% of non-responders, we aimed for 180
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23 189 participants.

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26 190 Statistical analysis was performed using SPSS 27 (IBM Corp, Armonk, NY, USA). Categorical
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28 191 variables were described as absolute (n) and relative frequencies (%). Continuous variables
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30 192 were described using mean and standard deviation. In order to control for possible confounding
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32 193 effects, interdependence of categorical variables with the three groups was tested using a Chi-
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34 194 squared test for contingency tables, and one-way analysis of variance (ANOVA) were used to
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36 195 test possible differences in the means of continuous variables between the three groups. For
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38 196 reliability testing of the checklist, internal consistency was evaluated with Chronbach's alpha.

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41 197 A one-way ANOVA was conducted to compare the means of the total OSCE score in
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43 198 percentages of the three groups. The number of previous attempts at i.v. cannulation using part-
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45 199 task trainer simulation and the number of previous attempts at human i.v. cannulation served
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47 200 as predictors in a multiple linear regression with the total score in percentage as dependent
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49 201 variable. To examine the influence of prior experience with i.v. cannulation on performance,
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51 202 multiple linear regression was performed. The OSCE total score in percentage served as the
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53 203 dependent variable, while the two variables "number of previous attempts at live i.v.
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55 204 cannulation" and "number of previous attempts at i.v. cannulation using part-task trainer
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simulation" served as predictors. A stepwise method was used to determine the influence of the predictors one by one. An a priori probability of less than 0.05 was considered to be statistically significant.

208

209 *Patient and Public Involvement*

210 No patient involved.

211

212 **Results**

213 Three hundred and sixteen students were invited to participate in the study. After excluding
214 students who did not attend the OSCE or arrived late, 309 students were enrolled (participation
215 rate of 97.8%). The participants' characteristics did not differ between the three groups (Table
216 2). Overall, the items in the checklist showed an internal consistency of $\alpha = 0.691$, which is
217 considered acceptable[27].

218 **Table 2:** Participants' characteristics

	Total	Mental	Part-Task	Written	p-value
	(n=309)	Imagery	Trainer	Instructions	
		(n=104)	(n=100)	(n=105)	
Age, years (mean \pm SD)	21.3 \pm 1.9	21.1 \pm 1.9	21.2 \pm 1.7	21.6 \pm 2.2	0.500
Female sex, n (%)	189 (61.2)	64 (62.1)	69 (68.3)	56 (53.3)	0.085*
German mother tongue, n (%)	282 (91.0)	92 (89.3)	92 (91.1)	98 (92.5)	0.545*
No previous experience in healthcare, n (%)	301 (97.4)	101 (98.1)	96 (95.0)	104 (98.1)	0.563*
Individual sum of previous attempts at i.v.-cannulation in part-	3.0 \pm 1.9	3.1 \pm 1.9	2.9 \pm 1.9	3.0 \pm 1.9	0.693

 task trainer simulation, n

(mean±SD)

Individual sum of previous

attempts at human i.v.cannulation, 3.2±8.0 2.3±1.9 3.8±9.0 3.6±10.4 0.372

n (mean±SD)

 219 *Chi-square

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221 Figure 2 shows a histogram of the students' overall performance (in percentage). There was no
 222 statistically significant difference between groups in the one-way ANOVA on our primary
 223 outcome total score in percentage of the OSCE assessment: mental imagery scored
 224 72.0±17.9%, part-task trainer simulation scored 74.4±15.6%, and written instructions scored
 225 69.9±16.6% ($F_{2,306} = 1.856, p = 0.158$).

226 Stepwise multiple linear regression showed that i.v.-cannulation experience during part-task
 227 trainer simulation had a significant but small effect on the OSCE performance (R^2
 228 = 0.015, $p = 0.031$). We performed diagnostics on the regression model and verified that the
 229 checked assumptions were met. Students reported the number of previous attempts at
 230 cannulation as 6.5±8.5, without differences between the three groups ($p=0.224$). The human
 231 i.v.-cannulation experience showed no additional contribution to the OSCE performance
 232 ($Beta In = 0.072, t = 1.245, p = 0.214$) and the simple correlation between these two
 233 variables is not significant ($r = 0.091, p = 0.113$).

234 Discussion

235 Our study shows that the performance of i.v. cannulation, assessed at an objective, structured
236 skills exam, did not differ after three different refresher tutorials (mental imagery, part-task
237 trainer simulation, and written instructions).

238 Our results differ from those of several randomised controlled trials on mental imagery in
239 postgraduate education. Studies that involved surgical trainees' "warming up" with mental
240 imagery [16, 17] described significantly improved performance with a warm-up before
241 laparoscopic surgery. However, when considering the effects of warm-up on the different
242 aspects of psychomotor performance, Paschold et al. [28] found that these were affected by the
243 nature of the warm-up, the type of surgery, and the expertise of the surgeon. This suggests that
244 optimal warm-up strategies are task- and procedure-specific and may change with varying
245 expertise [19], consequently yielding conflicting results.

246 Use of mental imagery in anaesthesia studies also showed conflicting findings. A 2016 study
247 reported improved fiberoptic intubation skills after a 5-minute mental imagery warm-up on a
248 virtual reality bronchoscopy simulator when compared with a control group [29]. In contrast,
249 anaesthetists practicing mental imagery did not manage crises better during simulation [30].
250 The reasons proposed by the study authors for the negative results were the nature of the task,
251 the limited "dose" effect (20 min vs. the 30–90 min reported in successful interventions), and
252 the number reduced of cues in the mental script.

253 More recently, comparable effects of mental imagery and low-fidelity simulation were
254 described in anaesthesiology residents learning to administer epidural anaesthesia [31]. Our
255 study results align with the latter, as all three "warm-up" methods resulted in similar student
256 performance in an objective, structured skills exam.

257 It is of more interest to compare our results with the study by Sanders et al. [20]. They also did
258 not find a significant difference in medical students' venipuncture performance with or without

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3 259 mental imagery. But they did find a significant difference in student performance between part-
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5 260 task trainer simulation and a control. Those authors assessed their students immediately after
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8 261 their training session, while our assessment occurred following the refresher, at 6 months after
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10 262 the initial training. Thus, the two studies might not be readily comparable.

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12 263 The number of previous i.v.-cannulation part-task trainer simulation attempts had a small but
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14 264 significant effect on the OSCE performance. Students in our study performed, on average, more
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16 265 than six attempts at i.v. cannulation in the 6 months before their first-year OSCE. This number
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18 266 is considered as the number of attempts necessary to achieve a plateau level of the learning
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20 267 curve for this procedure [6, 32]. Additionally, our results may simply reflect that the part-task
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22 268 trainer was effective in teaching the cannulation skills. That might partly explain why the three
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24 269 different refresher strategies resulted in comparable results. As our study participants reached
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26 270 the critical mass of medical students who had already acquired the necessary skills in i.v.-
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28 271 cannulation before the study took place, an improvement might be hard to detect, and our
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30 272 students probably did not necessarily profit from these refreshers. That might explain the
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32 273 puzzling finding in our study that the written instructions group was just as effective as the
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34 274 other two interventions, and questions the need for such a refresher shortly before an OSCE at
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36 275 all.
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42 276 Although we did not formally assess the cost of our three interventions, it seems obvious that
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44 277 written instructions and mental imagery are far more economical than the purchase and
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46 278 maintenance of a low-fidelity part-task arm, including the instructor's salary and time spent
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48 279 teaching). This cost-effectiveness argument needs to be further investigated in a properly
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50 280 performed cost-effectiveness analysis.
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53 281 Our study has several other limitations. It assessed the effectiveness of different refresher
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55 282 techniques for i.v.-cannulation skills, but its successful transfer to clinical practice could not
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57 283 be ascertained. We assume that our results can be applied to related techniques which require
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3 284 venipuncture, like taking blood samples, but despite our robust design, our results may not be
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5 285 generalizable to other cohorts. Additionally, due to the post-test methodology of the study, no
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8 286 conclusion can be taken regarding the student's performance of i.v. cannulation before the
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10 287 intervention. Finally, it is possible that the 6-minute intervention was simply too short to detect
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12 288 a difference in the teaching strategy and its effect on the performance of the skill.

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15 289 In summary, these results suggest that all interventions were successful at refreshing i.v.-
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17 290 cannulation procedures in undergraduate medical students.

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19 **291 Conclusions:**

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21 292 Medical schools currently seek to offer more efficient, cost-effective and innovative methods
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23 293 to enhance learning. Our study comparing three 6-minute refresher strategies, indicates that
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26 294 part-task trainer simulation is not superior to mental imagery and written instructions for
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28 295 refreshing i.v.-cannulation skills in first-year medical students. Both mental imagery and
29
30 296 written instructions have a far better effort-return ratio than resource-intensive hands-on
31
32
33 297 training with part-task trainer simulation. Mental imagery and written instructions cannot
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35 298 completely replace physical clinical skills training in i.v. cannulation, but may effectively
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37 299 supplement it, similar to other fields involving complex psychomotor skill learning.
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3 **300 Declarations**
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5 **301 Ethics approval and consent to participate:** All participants provided written informed
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7 **302** consent to participate and the Bern Cantonal Ethics Committee (Req-2021-00096, 26.01.2021)
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9
10 **303** waived the need for ethical approval as no patients were involved.
11

12 **304 Consent for publication:** Not applicable
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14 **305 Availability of data and materials:** All data relevant to the study are included in the article
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16
17 **306** or uploaded as supplementary information. Datasets containing student information are
18
19 **307** available after anonymisation from the corresponding author on reasonable request. The
20
21 **308** remaining data are available in a public, open access repository information at
22
23 **309** <https://doi.org/10.1257/rct.8043-1.0> [24].
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26 **310**

27
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29
30 **312** Resuscitation Council, the Task Force Chair Education, Implementation, and Team of ILCOR,
31
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35
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38
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41 **317** Switzerland
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44 **318**

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46
47 **319 Author contributions:**
48

49 **320** JBE wrote the outline and performed the data collection, demographic statistical analysis and
50
51 **321** interpretation of the data.
52

53 **322** RB and MB contributed to the outline, performed the data collection, and helped in data
54
55 **323** interpretation and the writing process.
56
57

58 **324** DS performed the bivariate statistical analysis and helped interpret the data.
59
60

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3 325 RG initiated the study, supervised the creation and adaptation of the outline, and critically
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5 326 reviewed the manuscript.

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7
8 327 CB supervised the creation and adaptation of the outline, performed data collection and helped
9
10 328 in data interpretation and the writing process.

11
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360 **References:**

- 361 1. Santen SA, Hemphill RR, McDonald MF, Jo CO. Patients' willingness to allow
362 residents to learn to practice medical procedures. *Acad Med.* 2004;79(2):144-7.
- 363 2. Berger-Estilita JM, Greif R, Berendonk C, Stricker D, Schnabel KP. Simulated
364 patient-based teaching of medical students improves pre-anaesthetic assessment: A rater-
365 blinded randomised controlled trial. *Eur J Anaesthesiol.* 2020;37(5):387-93.
- 366 3. Cook DA, Brydges R, Zendejas B, Hamstra SJ, Hatala R. Mastery learning for health
367 professionals using technology-enhanced simulation: a systematic review and meta-analysis.
368 *Acad Med.* 2013;88(8):1178-86.
- 369 4. McWilliams LA, Malecha A. Comparing Intravenous Insertion Instructional Methods
370 with Haptic Simulators. *Nurs Res Pract.* 2017;2017:4685157.
- 371 5. Lund F, Schultz JH, Maatouk I, Krautter M, Moltner A, Werner A, et al.
372 Effectiveness of IV cannulation skills laboratory training and its transfer into clinical
373 practice: a randomized, controlled trial. *PLoS One.* 2012;7(3):e32831.
- 374 6. Stolz LA, Cappa AR, Minckler MR, Stolz U, Wyatt RG, Binger CW, et al.
375 Prospective evaluation of the learning curve for ultrasound-guided peripheral intravenous
376 catheter placement. *J Vasc Access.* 2016;17(4):366-70.
- 377 7. Eggimann P, Sax H, Pittet D. Catheter-related infections. *Microbes Infect.*
378 2004;6(11):1033-42.
- 379 8. Gueembe M, Perez-Granda MJ, Capdevila JA, Barberan J, Pinilla B, Martin-Rabadan
380 P, et al. Nationwide study on peripheral-venous-catheter-associated-bloodstream infections in
381 internal medicine departments. *J Hosp Infect.* 2017;97(3):260-6.
- 382 9. Ray-Barruel G, Xu H, Marsh N, Cooke M, Rickard CM. Effectiveness of insertion
383 and maintenance bundles in preventing peripheral intravenous catheter-related complications
384 and bloodstream infection in hospital patients: A systematic review. *Infect Dis Health.*
385 2019;24(3):152-68.
- 386 10. Jung EY, Park DK, Lee YH, Jo HS, Lim YS, Park RW. Evaluation of practical
387 exercises using an intravenous simulator incorporating virtual reality and haptics device
388 technologies. *Nurse Educ Today.* 2012;32(4):458-63.
- 389 11. Sanders CW, Sadoski M, van Walsum K, Bramson R, Wiprud R, Fossum TW.
390 Learning basic surgical skills with mental imagery: using the simulation centre in the mind.
391 *Med Educ.* 2008;42(6):607-12.
- 392 12. Weller JM, Castanelli DJ, Chen Y, Jolly B. Making robust assessments of specialist
393 trainees' workplace performance. *Br J Anaesth.* 2017;118(2):207-14.
- 394 13. Rogers RG. Mental practice and acquisition of motor skills: examples from sports
395 training and surgical education. *Obstet Gynecol Clin North Am.* 2006;33(2):297-304, ix.
- 396 14. Cocks M, Moulton CA, Luu S, Cil T. What surgeons can learn from athletes: mental
397 practice in sports and surgery. *J Surg Educ.* 2014;71(2):262-9.
- 398 15. Martin J. Mental preparation for the 2014 Winter Paralympic Games. *Clin J Sport*
399 *Med.* 2012;22(1):70-3.
- 400 16. Abdalla G, Moran-Atkin E, Chen G, Schweitzer MA, Magnuson TH, Steele KE. The
401 effect of warm-up on surgical performance: a systematic review. *Surg Endosc.*
402 2015;29(6):1259-69.
- 403 17. Makhdom AM, Almaawi A, Tanzer D, Tanzer M. Does warming up improve surgical
404 outcome in total hip arthroplasty? *Eur J Orthop Surg Traumatol.* 2015;25(8):1265-9.
- 405 18. Moran-Atkin E, Abdalla G, Chen G, Magnuson TH, Lidor AO, Schweitzer MA, et al.
406 Preoperative warm-up the key to improved resident technique: a randomized study. *Surg*
407 *Endosc.* 2015;29(5):1057-63.

- 1
2
3 408 19. Weller JM. Improving procedural performance through warm-up and mental imagery.
4 409 Br J Anaesth. 2016;116(3):315-7.
5 410 20. Sanders CW, Sadoski M, Wasserman RM, Wiprud R, English M, Bramson R.
6 411 Comparing the Effects of Physical Practice and Mental Imagery Rehearsal on Learning Basic
7 412 Venipuncture by Medical Students. *Imagination, Cognition and Personality*. 2007;27(2):117-
8 413 27.
9 414 21. World Medical Association, WMA. Declaration of Helsinki: Ethical principles for
10 415 medical research involving human subjects 2018 [Available from:
11 416 [https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-](https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/)
12 417 [medical-research-involving-human-subjects/](https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/).
13 418 22. gov.uk. Data Protection Act 2018 [Available from:
14 419 <https://www.legislation.gov.uk/ukpga/2018/12/contents/enacted>.
15 420 23. fedlex.admin.ch. Verordnung über klinische Versuche in der Humanforschung 2013
16 421 [Available from: <https://www.admin.ch/opc/de/official-compilation/2013/3407.pdf>.
17 422 24. [dataset] Berger-Estilita J. Refreshing iv cannulation skills using mental imagery in
18 423 medical students: Rater-blinded three-arm intervention. AEA RCT Registry 2021.
19 424 25. Krueger RA. Focus groups: A practical guide for applied research: Sage publications;
20 425 2014.
21 426 26. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power
22 427 analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*.
23 428 2007;39(2):175-91.
24 429 27. Taber KS. The Use of Cronbach's Alpha When Developing and Reporting Research
25 430 Instruments in Science Education. *Research in Science Education*. 2018;48(6):1273-96.
26 431 28. Paschold M, Huber T, Kauff DW, Buchheim K, Lang H, Kneist W. Preconditioning
27 432 in laparoscopic surgery--results of a virtual reality pilot study. *Langenbecks Arch Surg*.
28 433 2014;399(7):889-95.
29 434 29. Samuelson ST, Burnett G, Sim AJ, Hofer I, Weinberg AD, Goldberg A, et al.
30 435 Simulation as a set-up for technical proficiency: can a virtual warm-up improve live fibre-
31 436 optic intubation? *Br J Anaesth*. 2016;116(3):398-404.
32 437 30. Hayter MA, Bould MD, Afsari M, Riem N, Chiu M, Boet S. Does warm-up using
33 438 mental practice improve crisis resource management performance? A simulation study. *Br J*
34 439 *Anaesth*. 2013;110(2):299-304.
35 440 31. Lim G, Krohner RG, Metro DG, Rosario BL, Jeong JH, Sakai T. Low-Fidelity Haptic
36 441 Simulation Versus Mental Imagery Training for Epidural Anesthesia Technical Achievement
37 442 in Novice Anesthesiology Residents: A Randomized Comparative Study. *Anesth Analg*.
38 443 2016;122(5):1516-23.
39 444 32. Loukas C, Nikiteas N, Kanakis M, Moutsatsos A, Leandros E, Georgiou E. A virtual
40 445 reality simulation curriculum for intravenous cannulation training. *Acad Emerg Med*.
41 446 2010;17(10):1142-5.
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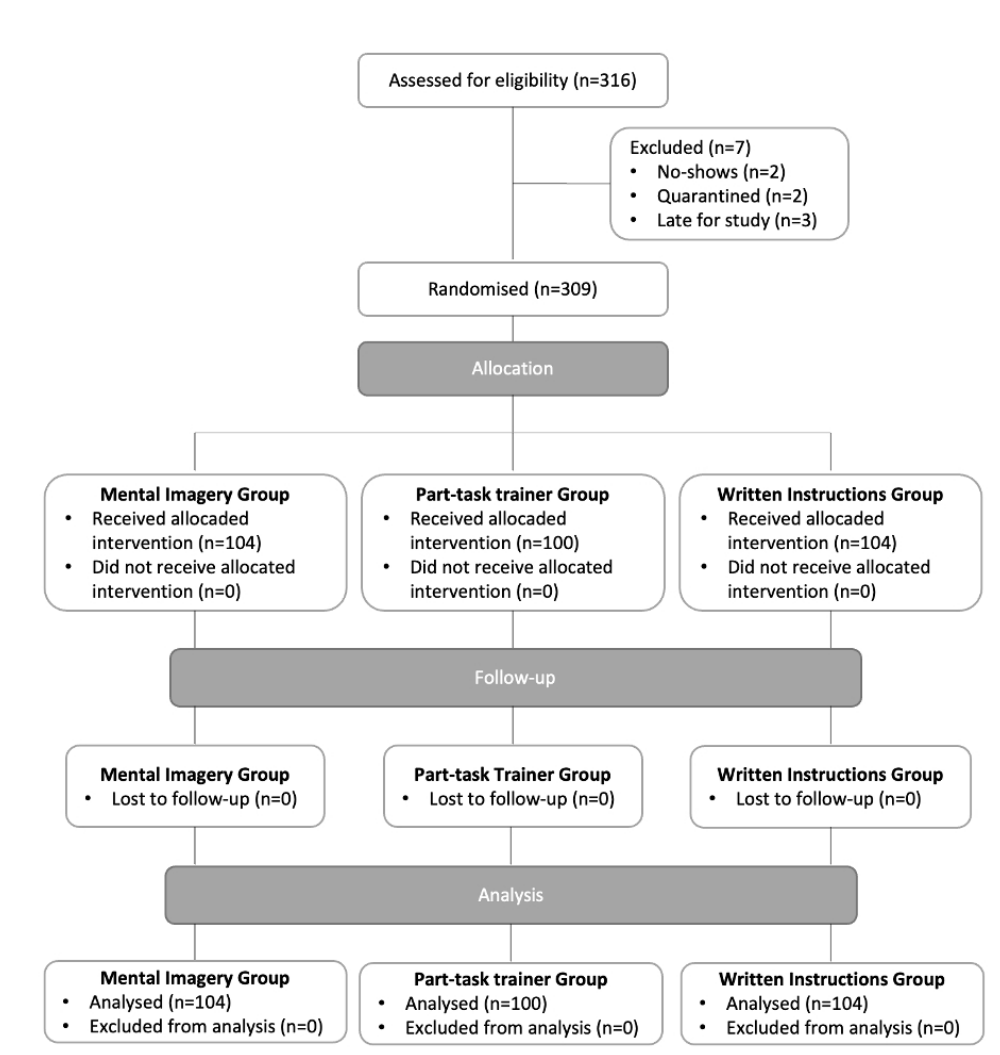
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3 448 **Figures:**
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5 449 **Figure 1:** Study Flowchart
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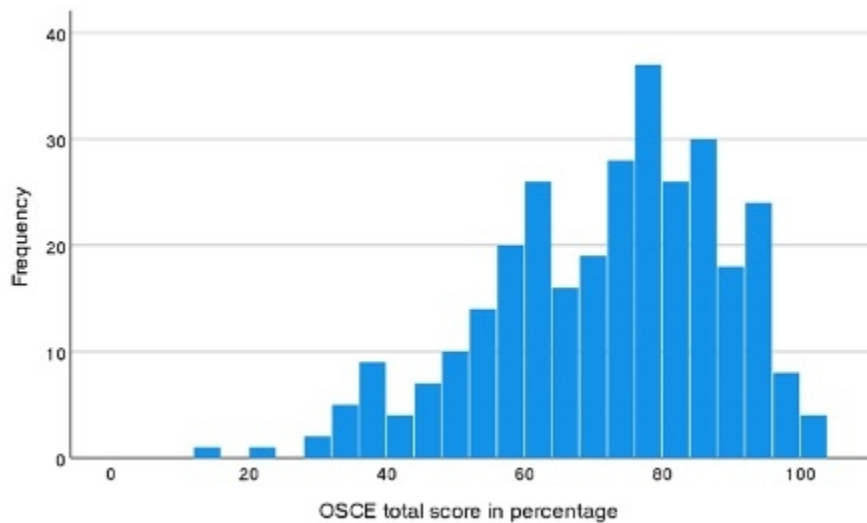
8 451 **Figure 2:** Histogram of OSCE total performance (in percentage)
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For peer review only



Study Flowchart

159x167mm (150 x 150 DPI)



Histogram of OSCE total performance (in percentage)

159x93mm (72 x 72 DPI)

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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	5
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	6
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	5
	4b	Settings and locations where the data were collected	5-6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	5-7
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	8-9
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	8
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	7
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	7
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	7
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	7
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	7

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	6
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	8-9
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	9
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	Fig. 1
	13b	For each group, losses and exclusions after randomisation, together with reasons	Fig. 1
Recruitment	14a	Dates defining the periods of recruitment and follow-up	N/A
	14b	Why the trial ended or was stopped	N/A
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Table 1
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	9
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	9
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	N/A
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	N/A
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	11
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	11
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	10-11
Other information			
Registration	23	Registration number and name of trial registry	5
Protocol	24	Where the full trial protocol can be accessed, if available	13
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	13

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.