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Supplemental Digital Table 1

Breakdown of Medical Education Research Study Quality Instrument (MERSQI)¹⁴ Scores of Studies

Study	Total MERSQI score*	Study design	Sampling	Type of data	Validity of evaluation instrument [†]	Data analysis	Outcomes
Britt, 2007 ²⁷	10.8	1.5	1.5	1	NA	2	3
Velmahos, 2004 ³⁵	15	3	2	3	1	3	3
Carvalho, 2007 ²⁶	9.6	1.5	1	1	NA	3	1.5
Sheretz, 2000 ¹¹	14.4	2	1	3	NA	3	3
Lee, 2009 ²⁸	12	1.5	2	3	1	3	1.5
Miranda, 2007 ³⁷	15.6	2	2	3	NA	3	3
Millington, 2009 ²⁹	13	1.5	2	3	2	3	1.5
Lenhard, 2008 ³⁸	11.4	2	2	1	NA	3	1.5
Barsuk, Am J Kidney Dis, 2009 ²⁵	14.5	2	3	3	2	3	1.5
Liachopoulou, 2008 ²⁴	12	2	2	1	3	3	1
Sanchez, 2006 ³⁰	9	1.5	1	1	NA	3	1
Nip, 2000 ³¹	10	1.5	1	3	0	3	1.5
Macnab, 1999 ³²	9.6	1.5	1	1	NA	3	1.5
Martin, 2003 ³⁹	14.4	2	1	3	1	2	3
Barsuk, Arch Intern Med,	15.6	2	2	3	NA	3	3

2009 ⁴⁰							
Barsuk, J Hosp Med, 2009 ⁴¹	15	2	2	3	2	3	3
Ault, 2006 ³³	10.2	1.5	2	1	NA	3	1
Rosen, 2009 ³⁴	11	1.5	1	3	1	3	1.5
Britt, 2009 ³⁶	14	3	2	3	0	3	3
Barsuk, Crit Care Med, 2009 ⁴²	15	2	2	3	2	3	3

* MERSQI score adjusted to a standard denominator of 18.

† NA = not applicable.

Supplemental Digital Table 2

Effect of Simulation-Based Central Venous Catheterization Educational Intervention on Learner Performance Outcomes *

Study	Domain assessed	Evaluation tool used	Evaluator	No. of trainer learners; control	Results of control learners	Results of trained learners	P-value
Performance Outcomes on Simulators							
Britt, 2007 ²⁷	Number of needle attempts, SC	NR	Unblinded instructor	n = 17	Pre: 1.5	Post: 1	NR
	Number of needle attempts, IJ	NR	Unblinded instructor		Pre: 1.9	Post: 1.3	NR
Carvalho, 2007 ²⁶	Average time taken, SC	NR	Unblinded student	NR	Pre: NR	Post: Decrease by 14 ± 4 sec (25%)	<.05
	Average time taken, IJ	NR	Unblinded student		Pre: NR	Post: Decrease by 24 ± 7 sec (35%)	<.05
Lee, 2009 ²⁸	Overall performance, IJ	19-item checklist	2 blinded evaluators	n = 16	Pre: 12/19	Post: 13.5/19	.01
	Overall performance, IJ	7-point global rating	2 blinded evaluators		Pre: 3.5/7	5.5/7	.01
	Average time taken to access vein, IJ				91 sec	60 sec	NR
Millington, 2009 ²⁹	Overall performance, IJ	10-item modified checklist ¹	2 blinded evaluators	n = 30	Pre: 7.8/10 ± 2.2/10; median 9	Post: 9.2/10 ± 0.8/10; median 9.5	<.001
	Overall performance, IJ	5-point global rating	2 blinded evaluators		Pre: median 3.5 (IQR 3-4)	Post: median 3.5 (IQR 4-4.5)	<.001
	Number of needle attempts, IJ	NR	2 blinded evaluators		Pre: 3.1 ± 4.1	Post: 1.4 ± 1.0	.04
	Number of catheter insertion attempts, IJ	NR	2 blinded evaluators		Pre: 1.1 ± 0.2	Post: 1.0 ± 0.2	.5
	Average time taken, IJ	NR	2 blinded evaluators		Pre: 9 min 47 sec ± 3 min 44 sec	Post: 7 min 20 sec ± 3 min	.02
Barsuk, Am J Kidney Dis, 2009 ²⁵	Overall performance, IJ	27-item checklist	Unblinded evaluator, with 50% validated by 2 nd blinded evaluator	n = 12	Pre: 29.5%	Post 88.6%	.002
	Overall performance, IJ	27-item checklist	Unblinded evaluator, with 50% validated by 2 nd blinded evaluator	n = 12; control n = 6 untrained second year fellows	Range 22-85%	67% higher than control	.001
Barsuk, J Hosp Med, 2009 ⁴¹	Overall performance, SC	27-item checklist	Unblinded evaluator, with 50% validated by 2 nd blinded evaluator	n = 28	Pre: 45.2%	Post: 91.1%	<.001
	Overall performance, IJ	27-item checklist	Unblinded evaluator, with		Pre: 48.4%	Post: 94.8%	<.001

	IJ		50% validated by 2 nd blinded evaluator				
Rosen, 2009 ³⁴	Overall performance, chicken, vein not specified	22-item checklist, but reported score out of 5	1 unblinded evaluator; (18% evaluated by 2 evaluators)	n = 20	Pre: 1.0/5 ± 0.8/5	Post: 4.4/5 ± 0.3/5	< .001
Barsuk, Crit Care Med, 2009 ⁴²	Overall performance, SC	27-item checklist	1 unblinded evaluator; (18% evaluated by 2 evaluators)	n = 76	Pre: 48.4% ± 26.8%	Post: 91.5% ± 17.1	<.0005
	Overall performance, IJ				Pre: 50.6% ± 23.4%	Post 93.9% ± 10.2%	<.0005
Performance Outcomes on Patients							
Britt, 2007 ²⁷	Time taken	NR	Self-report		First patient post-training: 43 min; range (15-90 min)	Tenth patient post-training: 22 min; range (10-45 min)	NR
Velmahos, 2004 ³⁵	Overall performance	14-item checklist	Blinded evaluator	n =12; control n = 14	7.5/14 ± 2.2/14	12.6/14 ± 1.1/14	<.001
	Number of catheter insertion attempts	NR	Blinded evaluator		1.6 ± 1.1	1.1 ± 0.3	.19
	Need for help from senior resident	NR	Blinded evaluator		0%	50%	.03
	Average Time taken	NR	Blinded evaluator		20.6 ± 9.1	15.4 ± 9.5	.14
	Overall performance	14-item checklist ²	Blinded evaluator		Last simulator performance: 12.9/14 ± 1/14	Patient performance: 12.6/14 ± 1.1/14	.99
Britt, 2009 ³⁶	Performance errors	NR	NR		19.9%	14.7%	.09
	Need for senior to take over	NR	NR		56%	35%	.11
Barsuk, Crit Care Med, 2009 ⁴²	Success rate	NR	Self-report		81%	95%	.005
Additional Learner Outcomes							
Sheretz, 2004 ¹¹	Use of full-size sterile drapes	Data from purchasing department		n =140	1 year before course: 44%	18 months after course: 65%	<.001
Miranda, 2007 ³⁷	Use of full-size sterile drapes	Self-report	Learner	n =16; control n = 38	74%	94%	.14
	Choosing internal jugular or subclavian over femoral site	Self-report and chart review	Learner and blinded evaluators	n =16; control n = 38	32%	38%	.67
Barsuk, J Hosp Med, 2009 ⁴¹	Number of CVC inserted without the	Self-report	Learner	n = 28; control n = 13	1/18	2/28	NS

	use of ultrasound						
Britt, 2009 ³⁵	Improper handwashing	Objective structured checklist	1 unblinded evaluator	n = 13; control n = 21	7.7%	8.8%	.80
	Improper drape	Objective structured checklist	1 unblinded evaluator	n = 13; control n = 21	17.9%	5.8%	.22
Barsuk, Crit Care Med, 2009 ⁴²	Use of ultrasound	Self-report	Learner	n = 76; control n = 27	94%	100%	NR

* Abbreviations: SC = subclavian; IJ = internal jugular; NR = Not reported.

Supplemental Digital Table 3

Effect of Simulation-Based Central Venous Catheterization Educational Intervention on Learner Knowledge and Confidence Outcomes *

Study	Sample size	Scale used	Results of pretraining [†]	Results of posttraining*	P-value
Knowledge					
Velmahos, 2002 ³⁵	n = 12	MCQ 15 questions	48.9% (SD = 7.1)	73.3% (SD = 12.4)	<.001
Sheretz, 2000 ¹¹	n = 109	Correctly identified that full-size sterile drapes should be used while inserting CVC (Y/N)	33%	99%	<.001
Miranda, 2007 ³⁷	n = 35	Correctly identified that complications most frequent at femoral site (Y/N)	77%	88%	NS
Millington, 2009 ²⁹	n = 30	MCQ 20 questions	65.7% (SD = 1.9)	81.2% (SD = 10.7)	<.001
Lenhard, 2008 ³⁸	n = 39	5-point scale: self perceived knowledge about indications, complications, procedure notes, sterile technique	80%	100%	<.001
Nip, 2000 ³¹	NR	Objective quiz	NR	NR	<.05
Martin, 2003 ³⁹	n = 105	Failure rate of Advanced Trauma Life Support course	8%	0%	NR
		Failure rate of the Fundamental Critical Care Support course	8.9%	0%	NR
Barsuk, Crit Care Med, 2009 ⁴²	n = 76	MCQ 40 questions	70.1% (SD = 7.7)	85.3 (SD = 4.8)	<.0005
Confidence					
Britt, 2007 ²⁷	n = 11	5-point scale: comfort with anatomy and procedure	NR	Anatomy: 3.8; Procedure: 2.6	N/A
Lee, 2009 ²⁸	n = 16	5-point scale; confidence performing ultrasound-guided CVC	32%	82%	<.01
Miranda, 2007 ³⁷	n = 35	I feel confident in Femoral	53%	59%	<.05

		CVC (Y/N)			
		Internal jugular (Y/N)	41%	71%	<.01
		Subclavian (Y/N)	24%	65%	<.01
Millington, 2009 ²⁹	n = 30	5-point scale	60%	80%	<.001
Lenhard, 2008 ³⁸	n = 39	Comfortable performing femoral CVC (Y/N)	62%	98%	.003
		Internal jugular (Y/N)	54%	88%	<.001
		Subclavian (Y/N)	26%	58%	.049
Barsuk, Am J Kidney Dis, 2009 ²⁵	n = 12	5-point scale.	50.5%	90%	.01
Liachopoulou, 2008 ²⁴	n = 44	10-point scale; confidence in femoral CVC	21% (SD = 26)	67% (SD = 20)	<.001
		Internal jugular vein	16% (SD = 22)	42% (SD = 29)	<.001
		Subclavian vein	17% (SD = 24)	61% (SD = 22)	<.001
Sanchez, 2006 ³⁰	n = 20	5-point scale	75% (SD = 25)	84% (SD = 17)	.025
Nip, 2000 ³¹	NR	NR	NR	"Felt more confident"	NR
Macnab, 1999 ³²	n = 64	5-point scale	29.6% (SD = 14)	80% (SD = 7)	Sig
Barsuk, J Hosp Med, 2009 ⁴¹	n = 28; n=13 untrained	100-point scale	Control: 68% (SD = 20)	Trained: 81% (SD = 11)	.02
Ault, 2006 ³³	n = 116	5-point scale; comfort with ultrasound	36%	76%	<.0001
Britt, 2009 ³⁶	n = 34; control n = 39	5-point scale; evaluator assessed resident comfort	Control: 58.4% (SD = 17.4)	Trained: 67% (SD = 16.8)	.03
Barsuk, Crit Care Med, 2009 ⁴²	n = 76; control n = 27	100-point scale	Control: 83% (SD = 15.9)	Trained: 87% (SD = 13.2)	.08

* Abbreviations: MCQ = Multiple choice questions); CVC = Central venous catheter; Y/N = Yes/No); NS = Not significant); NR = Not reported.

† Likert scale scores are converted to percentages wherever possible.

Supplemental Digital Table 4

Effect of Simulation-Based Central Venous Catheterization Educational Intervention on Patient Clinical Outcomes *

Study	Evaluation tool used	Evaluator	No. of trainer learners; control	Results of control learners	Results of trained learners	P-value
Number of needle passes						
Britt, 2007 ²⁷	NR	Self-report	n = 17	First patient post-training: 1.8; range (1-3)	Tenth patient post-training: 1.4; (range 1-3)	
Velmahos, 2004 ³⁵	NR	Blinded evaluator	n =12; control n = 14	6.4 (SD = 4.2)	3.3 ± 2.2	.05
Barsuk, J Hosp Med, 2009 ⁴¹	NR	Self-report	n = 28; control n = 13	2.78 (SD = 1.77)	1.79 ± 1.03	.04
Britt, 2009 ³⁶	Objective structured checklist	1 unblinded evaluator	n = 13; control n = 21	2.59 (SD =1.41)	2.41 ± 1.86	.64
Barsuk, Crit Care Med, 2009 ⁴²	NR	Self-report	n = 76; control n = 27	1.74 (SD = 0.83)	1.32 ± 0.85	<.0005
Arterial puncture						
Britt, 2007 ²⁷	Self-report	Learner	n = 11	NR	0/110 CVC placed	NR
Velmahos et al, 2004 ³⁵	NR	1 blinded evaluator	n =12; control n = 14	1/14 CVC	0/12 CVC	.35
Barsuk, J Hosp Med, 2009 ⁴¹	Self-report	Learner	n = 28; control n = 13	2/18	2/28	.65
Britt, 2009 ³⁶	NR	NR	n = 13; control n = 21	1/39 CVC	0/34 CVC	.96
Barsuk, Crit Care Med, 2009 ⁴²	NR	NR	n = 76; control n = 27	6/42 CVC	1/122 CVC	<.0005
Pneumothorax						
Britt, 2007 ²⁷	Self-report	Learner	n = 11	NR	0/110 CVC placed	NR
Velmahos, 2004 ³⁵	NR	1 blinded evaluator	n =12; control n = 14	1/14 CVC	0/12 CVC	.35
Martin, 2003 ³⁹	NR	Review of computerized registries	NR	Pre (1996-1998): 61 per 5271 CVC placed = 1.16%	Post (1999-2000): 26 per 3637 CVC placed = 0.71%	.04
Barsuk, J Hosp Med, 2009 ⁴¹	Self-report	Learner	n = 28; control n = 13; Total of 46 CVC, 28 by trained, 18 by control	0/18	0/28	1.00
Britt, 2009 ³⁶	NR	NR	n = 13;	4/39 CVC	0/34 CVC	.17

Barsuk, Crit Care Med, 2009 ⁴²	NR	NR	control n = 21 n = 76; control n = 27	1/42	2/122	.76
Catheter-related infection						
Sheretz, 2000 ¹¹	CDC	Hospital surveillance	n =140	3.29 infection/1000 CVC-days	2.36 infection/1000 CVC days	NR
Miranda, 2007 ³⁷	CDC	Chart review by blinded evaluators	n =16; control n = 38	0 infections/1000 CVC days	9.2 infection/1000 CVC-days	.29
Barsuk, Arch Intern Med, 2009 ⁴⁰	National Healthcare Safety Network	Medical record review by trained infection control personnel	n =92	Pre: 3.2 per 1000 CVC-days	Post: 0.5 per 1000 CVC-days	NR
			n =92 vs control in surgical ICU (n NR)	Surgical ICU (control): 4.86 per 1000 CVC days	Medical ICU pre-training: 3.2 per 1000 CVC days	.56
			n =92 vs control in surgical ICU (n NR)	Surgical ICU (control): 5.26 per 1000 CVC days	Medical ICU post-training: 0.5 per 1000 CVC days	.001
Britt, 2009 ³⁶	NR	NR	n = 13; control n = 21	3 per 595 CVC days	4 per 480 CVC days	.8

* Abbreviations: NR = Not reported); CVC = central venous catheter; CDC = Centers for Disease Control and Prevention surveillance definition).