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Assessing Physician Safety and Quality Knowledge

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Assessing Physician Safety and Quality Knowledge

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Abstract

Objective

It is well known that, for physicians to practice safe, high quality medicine, they must have sufficient safety and quality knowledge. Although a great deal is known about the safety and quality perceptions, attitudes, and beliefs of physicians, little is known about their safety and quality knowledge. This study tested the safety and quality knowledge of practicing primary care physicians.

Design

Prospective test of safety and quality knowledge

Setting

Primary care physicians practicing in the United States.

Participants

Study consisted of 518 U.S. practicing primary care physicians who answered an email invitation. It included 54% Family Medicine and 46% Internal Medicine physicians, who accepted an email invitation. The response rate was 66%.

Intervention

The physicians took a 24-question multiple-choice test over the Internet.

Outcome

The outcome was the percent correct.

Results

The average number of correct answers was 11.4 (SD, 2.69), 48% correct. Three common clinical vignettes questions were answered correctly by 45% of the physicians. Five physicians' knowledge of common radiation exposures questions were answered correctly by 40% of the physicians. Seven common healthcare quality and safety questions were answered correctly by 43% of the physicians. Seven Donabedian's model of structure, process, and outcome measure questions were answered correctly by 67% of the physicians. Two Institute of Medicine's definitions of quality and safety questions were answered correctly by 19.5% of the physicians.

Conclusion

Forty-eight percent of the physicians' answers to the safety and quality questions were correct. To our knowledge, this is the first assessment of the safety and quality knowledge of practicing U.S. primary care physicians.

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Strengths and limitations of this study

- A strength is that it consisted of practicing primary care physicians
- A strength is that it is representative of U.S. physicians
- A strength is its large sample size
- A limitation is that, although the questions were designed to assess enduring information, a few questions may be outdated and need to be discarded, at the times of the follow-up testing.

Funding sources

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Disclaimer

The findings and conclusions of this paper are those of the authors and do not necessarily represent the positions or views of the U.S. Department of Defense, the Military Health System, the Defense Health Agency, or the Uniformed Services University of the Health Sciences.

Disclosures

The Uniformed Services University of the Health Sciences institutional review board approved this study.

Conflicting and/or competing interests

The authors declare that they have no conflicts or competing interests.

Author contributions

Both authors contributed to the conception, creation, design, implementation, analysis, and presentation of the results.

Data sharing

The frequency counts for each question are shown in the Appendix.

Acknowledgments

None.

Introduction

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6 The landmark Institute of Medicine (IOM) report, *To Err Is Human: Building a Safer*
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8 *Health System*,¹ described a medical system that had become a clinical colossus, but its safety
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10 and quality had not kept pace with its size and complexity. It presented a system that was
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12 committing more errors yet detecting and correcting only a small fraction of them. It described a
13
14 system with significant safety and quality deficits, some of which resulted in patient injury and
15
16 death, and it recommended sweeping healthcare reforms.

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19 Since *To Err Is Human* was published more than 20 years ago, a great deal of work has
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21 been done on improving safety and quality,² yet a recent IOM report, *Best Care at Lower Cost:*
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23 *The Path to Continuously Learning Health Care in America*,³ and a recent study,⁴ suggest that
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25 many of the errors reported in *To Err Is Human* are continuing. The persistence and frequency of
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27 errors, and our reduced tolerance for errors, has heightened the importance³ in medical safety and
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29 quality.

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32 Although a great deal is known about the safety and quality perceptions, attitudes, and
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34 beliefs of physicians,⁵⁻⁹ little is known about their safety and quality knowledge. We designed a
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36 cross-sectional test of the safety and quality knowledge of practicing physicians. We believe this
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38 to be the first test of the safety and quality knowledge of practicing U.S. primary care physicians.

39 40 41 42 43 44 **Methods**

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47 This is a cross-sectional test of the safety and quality knowledge of practicing United
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49 States (U.S.) General Internal Medicine and Family Medicine physicians. Its participants were
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51 drawn from a national panel of physicians registered in Medscape. Physicians who completed the
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53 test received a \$30.00 Amazon gift card. The test was budgeted for 518 physicians completing
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Physician safety & quality knowledge

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3 the test. Seven hundred and eighty-eight practicing primary care physicians were randomly
4 selected and solicited, which resulted in a 66% response rate. The test instrument was web-based
5 and consisted of 24 multiple-choice questions. The questions were taken from widely available
6 safety and quality textbooks and clinical literature, it did not assume expert safety and quality
7 knowledge and, for the most part, represented enduring information. The questions, and their
8 references, are shown in the Appendix. The questions were presented in a random order and no
9 changes were made to the questions during testing. The only instruction the physicians received
10 was that they had to answer all the questions. The deidentified results were sent to the
11 investigators. The questions were not weighted. For each question, the percent correct is
12 calculated and, for each topic, the average percent correct was calculated. The Chi-square test
13 was used to assess demographic differences and whether the categorial answer frequencies
14 differed from chance, and the Student's t-test was used to compare continuous variables. The
15 tests were performed using R (www.R-project.org) and significance was set at a probability of
16 less than 0.05. The Uniformed Services University Institutional Review Board approved this
17 research.
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Results

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44 The study demographics of the 518 physicians are shown in Table 1. The medical
45 specialty of the participants was 46% General Internal Medicine and 54% Family Medicine. The
46 gender of the participants was 64% male and 35% female. There were no significant differences
47 between the participants and practicing physicians in terms of specialty, gender, and age.^{10,11}
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60 There were no significant differences in the test scores within specialty, gender, and age, except

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3 for slightly lower scores for physicians over 60 years of age compared to those under 60 years of
4 age, 0.45 (SD, 0.12) and 0.48 (SD, 0.11) respectively, $p = 0.003$. The median time to take the test
5 was 10.1 minutes.
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10 The average number of correct answers was 11.4 (SD, 2.69), 48% correct. Every
11 physician answered at least four questions correctly and no physician answered more than 20
12 questions correctly (Figure 1). For each question, the distribution of answers was significantly
13 different from that expected by chance. The mean percent correct for each of the five topics is
14 shown in Figure 2.
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22 Three common patient management vignettes addressed the physician's clinical quality
23 knowledge. There were five choices per question. The average number of correct answers was
24 1.3 (SD, 0.90), 45% correct. Fifty-five percent of the physicians knew how to manage a woman
25 with breast cancer who tested positive for a deleterious BRCA mutation; 46%, knew the work up
26 for an indeterminate renal mass; and 33%, knew the current approach to screening for lung
27 cancer. In terms of the renal mass, the American College of Radiology Appropriateness
28 Criteria¹² gave the computed tomography (CT) abdomen without and with intravenous (IV)
29 contrast the highest appropriateness rating, 9, but this modality also had the highest radiation
30 level. The ultrasound kidney retroperitoneal with duplex Doppler had the next highest rating, 8.
31 The ACR states that appropriateness ratings of 9, 8, and 7 are "Usually appropriate." Forty-six
32 percent of the physicians correctly balanced the radiation risk against the marginal additional
33 benefit of CT and chose the ultrasound test. These results are also consistent with a recent study
34 that found that physicians rarely have accurate expectations of the harms and benefits of clinical
35 interventions, which the investigators attributed to a lack of knowledge.¹³
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Physician safety & quality knowledge

Five questions addressed physicians' knowledge of common radiation risks. There were four choices per question, each choice differed by one base-ten log. In other words, the four possible answers to the question spanned a four-log range. The average number of correct answers was 2.0 (SD, 1.14), 40% correct. Sixty-one percent of the physicians correctly identified the radiation exposure delivered by a chest x-ray, 60% correctly identified the radiation exposure delivered by a mammogram, but only 45% could correctly identify the radiation exposure delivered by a CT scan of the abdomen and pelvis. Furthermore, in terms of population risk, only 25% of the physicians correctly chose the annual natural radiation exposure of an individual and only 11% knew the degree to which a 20 mSv of radiation exposure increased the population risk of a fatal cancer. These results are consistent with a systematic review of computed tomography and other radiographic procedures that found a similarly low level of radiology exposure knowledge among physicians.¹⁴

Seven questions addressed common healthcare system safety and quality issues. There were five choices per question. The average number of correct answers was 3.0 (SD, 1.27), 43% correct. Eighty-eight percent of the physicians knew the main hospital accrediting body, 74% knew the definition of beneficence, and 53% knew the Swiss Cheese model of accidents. But their accuracy was lower for questions regarding quality improvement tools, medication errors, 6-sigma, and harm detection – which were answered correctly by 34%, 19%, 19%, and 14% of the physicians, respectively. These results are consistent with a recent study of generalist and subspecialist Internal Medicine physicians which found that they correctly answered 43% of the questions regarding the U.S. Food and Drug Administration approval process.¹⁵ They are also consistent with a study of physician knowledge of central line-associated blood stream infection quality metrics that found that they answered 61% of the questions correctly.¹⁶

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Seven questions addressed Donabedian's¹⁷ model for assessing safety and quality in terms of structure, process, and outcomes. There were three choices per question. The average number of correct answers was 4.7 (SD, 1.50), 67% correct. This set of questions contained the easiest question, namely, whether "The percentage of patients who are satisfied with their care" was a structure, process, or outcome measure. Ninety-six percent of the physicians correctly answered that it was an outcome. The physicians were highly accurate on classifying nosocomial infections, 89%, and staffing, 84%, but they were only 53% correct in classifying beta-blockers, 53% correct in classifying credentials, 50% correct in classifying the diabetic foot exam, and 45% correct in classifying discharge instructions.

Two questions asked physicians to identify common safety and quality definitions from the IOM. There were five choices per question. The average number of correct answers was 0.39 (SD, 0.54), 20% correct. The definitions were published 19 years ago in *To Err Is Human*. Despite the high visibility of *To Err Is Human*, only 33% of the physicians correctly identified the IOM definition of quality. The most difficult of the 24 questions was the IOM's definition of safety. Limiting the definition to "freedom from accidental injury," would not have distinguished it from other safety definitions. Therefore, the correct answer included the rest of the IOM definition, "where accidental injury can be due to error, as either the failure of a planned action to be completed as intended or the use of the wrong plan to achieve an aim." Only six percent of physicians knew the correct definition.

Conclusions

U.S. physicians answered forty-eight percent of the safety and quality questions correctly. They performed best on questions that required little safety and quality knowledge and worst on

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question that required basic safety and quality knowledge. Our population was similar to the U.S. physician population in terms of specialty, gender, and age. There were no significant differences within specialty, gender, or age; although the scores of physicians over 60 years of age were slightly lower. These results are consistent with studies of physician knowledge of clinical harms and benefits,¹³ radiology knowledge,¹⁴ knowledge of the FDA approval process,¹⁵ and of quality metrics.¹⁶

Physicians want to practice safe, high quality medicine,¹⁸ but they may not be aware of how much they need to know about safety and quality. Furthermore, physicians need time to learn about safety and quality, and they need the time and expertise required to use the information in their EHRs to monitor the safety and quality of their practice. Although many health care systems consider themselves to be healthcare learning systems,^{19,20} that belief does not always translate into their assisting frontline clinicians in improving their safety and quality knowledge.^{21,22}

It is clear that physicians require quality and safety training. The postgraduate Clinical Learning Environment Review (CLER) was created to instruct physicians in six areas, namely, patient safety, health care quality, care transitions, supervision, duty hours/fatigue management & mitigation, and professionalism.²³ It began to be implemented in 2015 and is now fully implemented. Our test was prior to the widespread implementation of CLER. We will assess primary care physicians' safety and quality knowledge in five years. Our expectation is that the younger physicians then will perform better than they did on this initial test, and that safety and quality knowledge will even improve among older physicians. Furthermore, we expect to observe more physician-directed quality and safety programs.²⁴

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3 The main limitation of this study is that, although the questions were designed to assess
4 enduring information, the two clinical questions and the two definitions may be outdated,
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6 resulting in 20 follow-up testing questions. Another limitation is that we may have overestimated
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8 physician knowledge because it used multiple-choice questions that probe recognition. Physician
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10 scores might have been substantially lower had they been asked to recall the correct answer to
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12 each question.
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17 In conclusion, forty-eight percent of the physicians' answers to the safety and quality
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19 questions were correct. A national system has been put in place at the resident level to improve
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21 physician safety and quality knowledge. Since knowledge is a prerequisite for performance, we
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23 expect that in the future physicians' increased knowledge will result in their improving their
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25 safety and quality performance. We believe this to be the first prospective test of the safety and
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27 quality knowledge of practicing U.S. primary care physicians.
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Figure legends

Figure 1. Percentage of subjects answering the questions correctly

Figure 2. Mean percent correct in each of the five topics

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Table 1. Physician characteristics^a

	Study population Number and Percent	National population Percent
Medical Specialty^b		
Family Medicine	280 (54%)	53%
Internal Medicine	238 (46%)	47%
Gender^c		
Male	331 (64%)	66%
Female	187 (36%)	34%
Age^c		
< 39	131 (25%)	21%
40 – 49	160 (31%)	24%
50 – 59	124 (24%)	24%
60 – 69	85 (17%)	20%
70 +	18 (3%)	11%

^aThere were no significant differences between the study population and the national population in terms of medical specialty, gender, or age.

^bNational: <https://www.ahrq.gov/research/findings/factsheets/primary/pcwork1/index.html>

^cNational: Young A, Chaudhry HJ, Pei X, Halbesleben K, Polk DH, Dugan M. A census of actively licensed physicians in the United States, 2014. *J Med Reg* 2015;101(2):8-23

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Table 2. Questions and percent correct (ordered from highest to lowest percentage correct)

Questions	Percent correct
Patient management (5 choices per question)	
A 42-year-old female presents to your clinic for the first time. She is s/p a left lumpectomy for unilateral breast cancer. You order a BRCA test, which comes back positive for a deleterious mutation. You recommend:	55%
A 22-year-old female transferred to your clinic from another facility. She sees you for the first time today. She states that she has a 2 cm indeterminate renal mass that was incidentally detected during a work-up for a suspected kidney stone almost 3 years ago. Her previous physician told her that it needed to be re-imaged within 3 years. She does not remember what imaging test was used to detect the mass. She denies any new symptoms or blood in her urine. She is here for an imaging test. Pick the best test.	46%
A retired 66-year-old man presents to your clinic for a routine physical examination. He has a history of COPD. You ask about his tobacco history and he tells you that he started smoking when he was 25 years old, he smoked 1 pack-per-day for 25 years, and he stopped smoking when he was 50 years old. He wants to know if he should do something to assess his risk of lung cancer. You order:	33%
Patient management mean percent correct	45%
Radiation risk (4 choices per question)	
The effective dose of a two-view chest radiograph is approximately:	61%
The effective dose of a two-view mammogram is approximately:	60%
The effective dose of a single CT of the abdomen and pelvis, with and without contrast is approximately:	45%
For the average American living at sea level, the annual effective dose of radiation is approximately:	25%
Receiving at least 20 mSv (millisieverts) of radiation increases an adult person's risk of a fatal cancer by approximately:	11%
Radiation risk mean percent correct	40%
General Safety and Quality (5 choices per question)	
The main hospital accreditation body in the United States is:	88%
Which one of the following refers to acting in the best interest of the patient?	74%
Which of the following is the correct description of the Swiss Cheese model of accidents?	53%
Select from the list below the method that is NOT a tool for analyzing quality improvement.	34%
Which of the following is NOT a part of "6-sigma?"	19%
The most frequent reason for hospital medication errors is:	19%
Several methods for detecting harms are shown below. Used in their usual way, which method detects the most harms?	14%
Safety mean percent correct	45%

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Structure, process, outcome (3 choices per question)	
The percentage of patients who are satisfied with their care.	96%
Percentage of patients that experience a nosocomial infection.	89%
There is enough clinical staff to care for the patients.	84%
The percentage of patients with an acute myocardial infarction who receive a beta-blocker.	53%
Clinicians are properly credentialed.	53%
The percentage of diabetic patients that have an order for an annual foot exam.	50%
The percentage of patients that are given discharge instructions.	45%
Structure, process, outcome mean percent correct	67%
Safety and quality definitions (IOM) (5 choices per question)	
The Institute of Medicine's definition of quality is:	33%
The Institute of Medicine's definition of safety is:	6%
Safety and quality definitions mean percent correct	20%
Grand mean percent correct	48%

Figure 1.

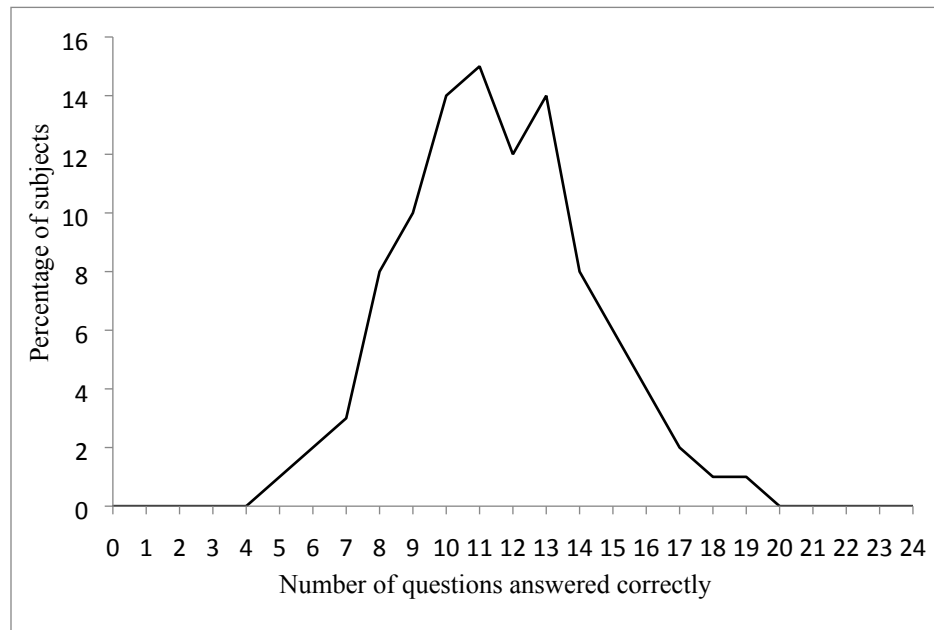
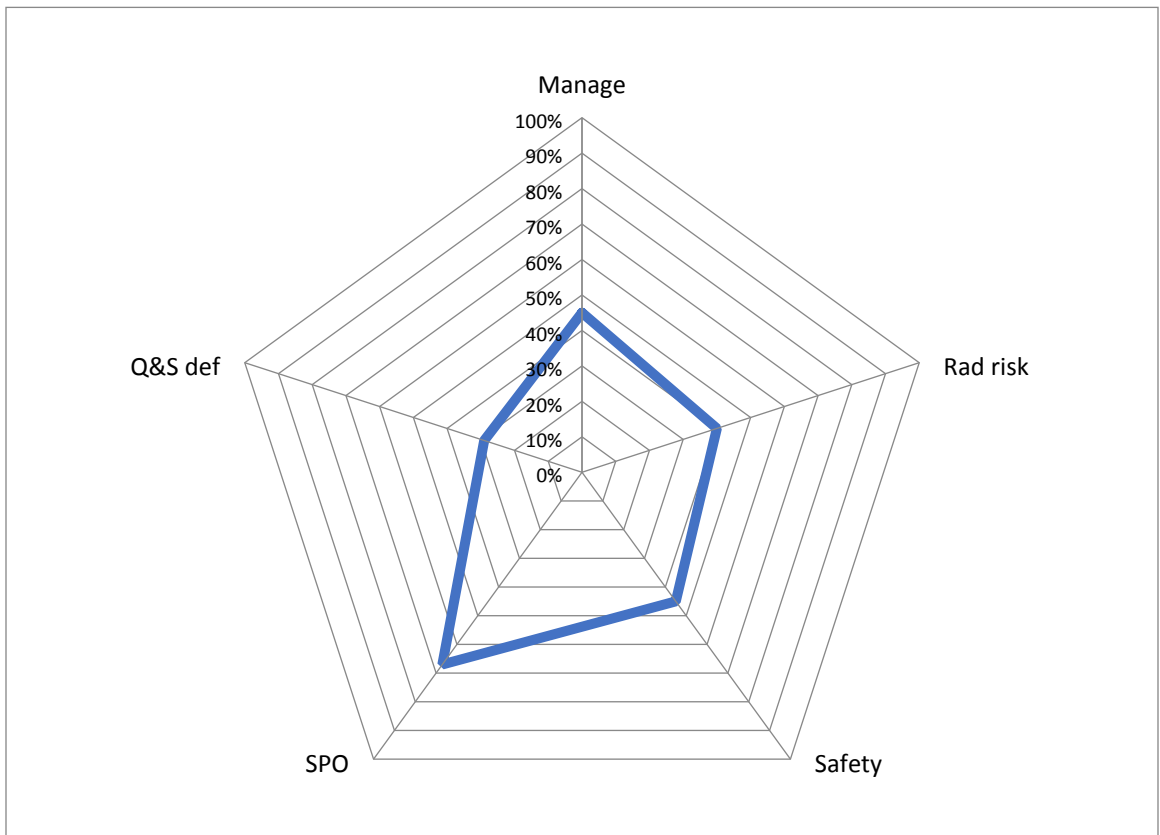


Figure 2.



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APPENDIX

The correct answers are in bold. In the test the questions were presented in random order, there were no results, the correct answers were not in bold, and the questions were not referenced.

PATIENT MANAGEMENT

A 42-year-old female presents to your clinic for the first time. She is s/p a left lumpectomy for unilateral breast cancer. You order a BRCA test, which comes back positive for a deleterious mutation. You recommend:

Left breast mastectomy	48 (9%)
Bilateral mastectomy	166 (32%)
Bilateral salpingo-oophorectomy	8 (2%)
Left breast mastectomy and bilateral salpingo-oophorectomy	13 (3%)
Bilateral mastectomy and bilateral salpingo-oophorectomy¹	283 (55%)

A 22-year-old female transferred to your clinic from another facility. She sees you for the first time today. She states that she has a 2 cm indeterminate renal mass that was incidentally detected during a work-up for a suspected kidney stone almost 3 years ago. Her previous physician told her that it needed to be re-imaged within 3 years. She does not remember what imaging test was used to detect the mass. She denies any new symptoms or blood in her urine. She is here for an imaging test. Pick the best test.

Arteriography kidney	1 (0%)
CT abdomen with and without contrast	114 (22%)
MRI abdomen without contrast	13 (3%)
X-ray intravenous urography	4 (1%)
CT abdomen without contrast	42 (8%)
MRI abdomen with and without contrast	32 (6%)
U/S kidney retroperitoneal with Doppler²	239 (46%)
CT abdomen with contrast	73 (14%)

A retired 66-year-old man presents to your clinic for a routine physical examination. He has a history of COPD. You ask about his tobacco history and he tells you that he started smoking when he was 25 years old, he smoked 1 pack-per-day for 25 years, and he stopped smoking when he was 50 years old. He wants to know if he should do something to assess his risk of lung cancer. You order:

No imaging³	173 (33%)
Chest x-ray, PA and lateral	72 (14%)
CT of the chest without contrast	35 (7%)
CT of the chest with and without contrast	16 (3%)
A low-dose CT of the chest	222 (43%)

RADIATION RISK

The effective dose of a two-view chest radiograph is approximately:

0.01 mSv (millisievert)	62 (12%)
0.1 mSv⁴	316 (61%)
1.0 mSv	112 (22%)
10.0 mSv	28 (5%)

The effective dose of a two-view mammogram is approximately:

0.04 mSv (millisievert)	116 (22%)
0.4 mSv⁵	313 (60%)
4.0 mSv	84 (16%)
40.0 mSv	5 (1%)

The effective dose of a single CT of the abdomen and pelvis, with and without contrast is approximately:

0.02 mSv (millisievert)	9 (2%)
0.2 mSv	69 (13%)
2.0 mSv	206 (40%)
20.0 mSv⁶	234 (45%)

For the average American living at sea level, the annual effective dose of radiation is approximately:

0.03 mSv (millisievert)	223 (43%)
0.3 mSv	148 (29%)
3.0 mSv⁷	127 (25%)
30.0 mSv	20 (4%)

Receiving at least 20 mSv (millisieverts) of radiation increases an adult person's risk of a fatal cancer by approximately:

1 in 100,000 – 1,000,000	116 (22%)
1 in 10,000 – 100,000	183 (35%)
1 in 1,000 – 10,000	164 (32%)
1 in 100 – 1,000⁸	55 (11%)

GENERAL SAFETY AND QUALITY

The main hospital accreditation body in the United States is:

Institute for Healthcare Improvement (IHI)	2 (0%)
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Physician safety & quality knowledge

American Hospital Association (AHA)	16 (3%)
National Committee for Quality Assurance (NCQA)	27 (5%)
The Joint Commission (JC)⁹	456 (88%)
Centers for Medicare and Medicaid Services (CMS)	17 (3%)

Which one of the following refers to acting in the best interest of the patient?

Respect for autonomy	60 (12%)
Beneficence¹⁰	382 (74%)
Nonmaleficence	62 (12%)
Justice	5 (1%)
Fairness	9 (2%)

Which of the following is the correct description of the Swiss cheese model of accidents?

Many people making the same mistake over and over again will eventually cause an accident.	65 (13%)
It usually takes several things going wrong for an accident to	274 (53%)
If a person makes the same mistake many times, it will eventually cause an accident.	57 (11%)
It is about filling in holes in the system.	108 (21%)
A person who makes a root cause error will cause an accident.	14 (3%)

Select from the list below the method that is NOT a tool for analyzing quality improvement.

Process mapping	20 (4%)
Flow charts	58 (11%)
Fishbone diagrams	127 (25%)
Discharge checklists¹²	177 (34%)
Pareto charts	136 (26%)

Which of the following is NOT a part of “6-sigma”?

Its goal is to reduce errors to a rate of 3.4 errors per million opportunities to make an error.	66 (13%)
It involves a series of five steps: define, measure, analyze, improve, and control.	93 (18%)
It is especially useful for processes that do not happen frequently.¹³	99 (19%)
Its practitioners are known as black belts.	165 (32%)
It is six standard deviations from the average.	95 (18%)

The most frequent reason for hospital medication errors is:

Prescribing¹⁴	98 (19%)
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Transcribing	244 (47%)
Dispensing	64 (12%)
Administration	93 (18%)
Monitoring	19 (4%)

Several methods for detecting harms are shown below. Used in their usual way, which method detects the most harms?

Direct observation of care	129 (25%)
Reports by clinicians	30 (6%)
IHI global trigger tools¹⁵	73 (14%)
AHRQ Patient Safety Indicators	169 (33%)
Chart reviews	117 (23%)

STRUCTURE, PROCESS, OUTCOME

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. The percentage of patients who are satisfied with their care.

S	6 (1%)
P	17 (3%)
O¹⁶	495 (96%)

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. Percentage of patients that experience a nosocomial infection.

S	18 (3%)
P	37 (7%)
O¹⁶	463 (89%)

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. There is enough clinical staff to care for the patients.

S¹⁶	436 (84%)
P	46 (9%)
O	36 (7%)

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. The percentage of patients with an acute myocardial infarction who receive a beta-blocker.

S	26 (5%)
P¹⁶	274 (53%)
O	218 (42%)

Identify whether this is an example of a structure (S), process (P), or outcome (O).

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Q. Clinicians are properly credentialed.

S ¹⁶	272 (53%)
P	226 (44%)
O	20 (4%)

Identify whether it is an example of a structure (S), process (P), or outcome (O).

Q. The percentage of diabetic patients that have an order for an annual foot exam.

S	55 (11%)
P ¹⁶	257 (50%)
O	206 (40%)

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. The percentage of patients that are given discharge instructions.

S	12 (2%)
P ¹⁶	234 (45%)
O	272 (53%)

QUALITY AND SAFETY DEFINITIONS

The Institute of Medicine's definition of quality is:

Providing acceptable and expected medical care, where acceptable means medical care that patients understand, agree to, and can afford, and expected means performance at the current professional standard of care.	183 (35%)
Doing the right thing at the right time for the right individual to get the best possible results.	75 (14%)
The degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge. ¹⁷	170 (33%)
A system in which organizations are accountable for continuously improving the quality of their services and safeguarding high standards of care.	65 (13%)
Receiving the best care possible for one's illness or condition.	25 (5%)

The Institute of Medicine's definition of safety is:

The minimization of the risk of any harm, and the amelioration of the effect of a harm, to a person caused by medical care.	135 (26%)
Freedom from accidental or preventable injuries produced by medical care.	60 (12%)

Assuring that all care is safe for all patients requires examining the systems and processes of care, identifying the points of failure, and modifying the factors that cause systems to break down.	90 (17%)
The avoidance, prevention, and amelioration of adverse outcomes or injuries stemming from the process of care.	200 (39%)
Freedom from accidental injury, where accidental injury can be due to error, as either the failure of a planned action to be completed as intended or the use of the wrong plan to achieve an aim.¹⁸	33 (6%)

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Assessing Physician Safety and Quality Knowledge

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Abstract

Objective

It is well known that, for physicians to practice safe, high quality medicine, they must have sufficient safety and quality knowledge. Although a great deal is known about the safety and quality perceptions, attitudes, and beliefs of physicians, little is known about their safety and quality knowledge. This study tested the safety and quality knowledge of practicing primary care physicians.

Design

Cross-sectional test of safety and quality knowledge

Setting

Primary care physicians practicing in the United States.

Participants

Study consisted of 518 U.S. practicing primary care physicians who answered an email invitation. It included 54% Family Medicine and 46% Internal Medicine physicians, who accepted an email invitation. The response rate was 66%.

Intervention

The physicians took a 24-question multiple-choice test over the Internet.

Outcome

The outcome was the percent correct.

Results

The average number of correct answers was 11.4 (SD, 2.69), 48% correct. Three common clinical vignettes questions were answered correctly by 45% of the physicians. Five physicians' knowledge of common radiation exposures questions were answered correctly by 40% of the physicians. Seven common healthcare quality and safety questions were answered correctly by 43% of the physicians. Seven Donabedian's model of structure, process, and outcome measure questions were answered correctly by 67% of the physicians. Two Institute of Medicine's definitions of quality and safety questions were answered correctly by 19.5% of the physicians.

Conclusion

Forty-eight percent of the physicians' answers to the safety and quality questions were correct. To our knowledge, this is the first assessment of the safety and quality knowledge of practicing U.S. primary care physicians.

Strengths and limitations of this study

- A strength is that it consisted of practicing primary care physicians
- A strength is that it is representative of U.S. physicians
- A strength is its large sample size
- A limitation is that, although the questions were designed to assess enduring information, a few questions may be outdated and need to be discarded, at the times of the follow-up testing.

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Disclaimer

The findings and conclusions of this paper are those of the authors and do not necessarily represent the positions or views of the U.S. Department of Defense, the Military Health System, the Defense Health Agency, or the Uniformed Services University of the Health Sciences.

Disclosures

The Uniformed Services University of the Health Sciences institutional review board approved this study.

Conflicting and/or competing interests

The authors declare that they have no conflicts or competing interests.

Author contributions

HB: originated the study idea and designed the research project, analyzed the study data and drafted the manuscript. HK: made important contributions to designing the research project and analyzing the study data, and made significant contributions to the writing of the manuscript.

Data sharing

The frequency counts for each question are shown in Table 2.

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None.

Patient and Public Involvement: No patient involved.

Introduction

The landmark Institute of Medicine (IOM) report, *To Err Is Human: Building a Safer Health System*,¹ described a medical system that had become a clinical colossus, but its safety and quality had not kept pace with its size and complexity. It presented a system that was committing more errors yet detecting and correcting only a small fraction of them. It described a system with significant safety and quality deficits, some of which resulted in patient injury and death, and it recommended sweeping healthcare reforms.

Since *To Err Is Human* was published more than 20 years ago, a great deal of work has been done on improving safety and quality,² yet a recent IOM report, *Best Care at Lower Cost: The Path to Continuously Learning Health Care in America*,³ and a recent study,⁴ suggest that many of the errors reported in *To Err Is Human* are continuing. The persistence and frequency of errors, and our reduced tolerance for errors, has heightened the importance³ in medical safety and quality.

Although a great deal is known about the safety and quality perceptions, attitudes, and beliefs of physicians,⁵⁻⁹ little is known about their safety and quality knowledge. We designed a cross-sectional test of the safety and quality knowledge of practicing physicians. We believe this to be the first test of the safety and quality knowledge of practicing U.S. primary care physicians.

Methods

This is a cross-sectional one-time test of the safety and quality knowledge of practicing United States (U.S.) General Internal Medicine and Family Medicine physicians. Its participants were drawn from a national panel of physicians registered in Medscape. Physicians who

Physician safety & quality knowledge

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3 completed the test received a \$30.00 Amazon gift card. The test was budgeted for 518 physicians
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5 completing the test. Seven hundred and eighty-eight practicing primary care physicians were
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7 randomly selected and solicited via email, which resulted in a 66% response rate. The test
8
9 instrument was web-based and consisted of 24 multiple-choice questions. The questions were
10
11 taken from widely available safety and quality textbooks and clinical literature, it did not assume
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13 expert safety and quality knowledge and, for the most part, represented enduring information.
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15 There were six areas of questions: patient management, radiation risk, general safety and quality,
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17 structure, process and outcome; and quality and safety definitions.
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22 In terms of patient management, three common patient management vignettes addressed
23
24 the physician's clinical quality knowledge. For the breast cancer vignette, there were five
25
26 possible answers. For the renal mass, the American College of Radiology (ACR)
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28 Appropriateness Criteria¹⁰ gave the computed tomography (CT) abdomen without and with
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30 intravenous (IV) contrast the highest appropriateness rating, 9, but this modality also had the
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32 highest radiation level. The ultrasound kidney retroperitoneal with duplex Doppler had the next
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34 highest rating, 8. The ACR states that appropriateness ratings of 9, 8, and 7 are "Usually
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36 appropriate." There were eight possible answers to the renal mass question. Finally, in terms of
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38 patient management, the lung cancer screening consisted of five possible answers.
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43 In terms of common radiation risks, five questions addressed physicians' knowledge of
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45 common radiation risks. There were four choices per question, each choice differed by one base-
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47 ten log. In other words, the four possible answers to the question spanned a four-log range.
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50 In terms of common healthcare system safety and quality issues, there were seven
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52 questions. There were five choices per question. In terms of Donabedian's¹¹ model for assessing
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54 safety and quality in terms of structure, process, and outcomes, there were seven questions.
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Physician safety & quality knowledge

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3 There were three choices per question. Two questions asked physicians to identify common
4 safety and quality definitions from the IOM. There were five choices per question. The most
5 difficult of the 24 questions was the IOM's definition of safety. Limiting the definition to
6 "freedom from accidental injury," would not have distinguished it from other safety definitions.
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8 Therefore, the correct answer included the rest of the IOM definition, "where accidental injury
9 can be due to error, as either the failure of a planned action to be completed as intended or the
10 use of the wrong plan to achieve an aim."
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19 The questions, and their references, are shown in Table 2.¹²⁻²⁹ The questions were
20 presented in a random order and no changes were made to the questions during testing. The only
21 instruction the physicians received was that they had to answer all the questions. The
22 deidentified results were sent to the investigators by Medscape. The questions were not
23 weighted. For each question, the percent correct is calculated and, for each topic, the average
24 percent correct was calculated. The Chi-square test was used to assess demographic differences
25 and whether the categorial answer frequencies differed from chance, and the Student's t-test was
26 used to compare continuous variables. The tests were performed using R (www.R-project.org)
27 and significance was set at a probability of less than 0.05. The Uniformed Services University
28 Institutional Review Board approved this research.
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45 Results

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47 The study demographics of the 518 physicians are shown in Table 1. The medical
48 specialty of the participants was 46% General Internal Medicine and 54% Family Medicine. The
49 gender of the participants was 64% male and 35% female. There were no significant differences
50 between the participants and practicing physicians in terms of specialty, gender, and age.^{30,31}
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Physician safety & quality knowledge

There were no significant differences in the test scores within specialty, gender, and age, except for slightly lower scores for physicians over 60 years of age compared to those under 60 years of age, 0.45 (SD, 0.12) and 0.48 (SD, 0.11) respectively, $p = 0.003$. The median time to take the test was 10.1 minutes.

The results are shown in Table 2. The average number of correct answers was 11.4 (SD, 2.69), 48% correct. Every physician answered at least four questions correctly and no physician answered more than 20 questions correctly (Figure 1). For each question, the distribution of answers was significantly different from that expected by chance ($p < 0.01$). The mean percent correct for each of the five topics is shown in Figure 2.

In terms of the three common management vignettes, the average number of correct answers was 1.3 (SD, 0.90), 45% correct. For the breast cancer vignette, fifty-five percent of the physicians knew how to manage a woman with breast cancer who tested positive for a deleterious BRCA mutation. For the renal mass vignette, 46%, knew the work up for an indeterminate renal mass. For the lung cancer screening, 33%, knew the current approach to screening for lung cancer. Forty-six percent of the physicians correctly balanced the radiation risk against the marginal additional benefit of CT and chose the ultrasound test. These results are also consistent with a recent study that found that physicians rarely have accurate expectations of the harms and benefits of clinical interventions, which the investigators attributed to a lack of knowledge.³²

In terms of common radiation risks, the average number of correct answers was 2.0 (SD, 1.14), 40% correct. Sixty-one percent of the physicians correctly identified the radiation exposure delivered by a chest x-ray, 60% correctly identified the radiation exposure delivered by a mammogram, but only 45%, could correctly identify the radiation exposure delivered by a CT

Physician safety & quality knowledge

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3 scan of the abdomen and pelvis. Furthermore, in terms of population risk, only 25% of the
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5 physicians correctly chose the annual natural radiation exposure of an individual and only 11%
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7 knew the degree to which a 20 mSv of radiation exposure increased the population risk of a fatal
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9 cancer. These results are consistent with a systematic review of computed tomography and other
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11 radiographic procedures that found a similarly low level of radiology exposure knowledge
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13 among physicians.³³
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17 In terms of commons healthcare system safety and quality issues, the average number of
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19 correct answers was 3.0 (SD, 1.27), 43% correct. Eighty-eight percent of the physicians knew the
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21 main hospital accrediting body, 74% knew the definition of beneficence, and 53% knew the
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23 Swiss Cheese model of accidents. But their accuracy was lower for questions regarding quality
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25 improvement tools, medication errors, 6-sigma, and harm detection – which were answered
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27 correctly by 34%, 19%, 19%, and 14% of the physicians, respectively. These results are
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29 consistent with a recent study of generalist and subspecialist Internal Medicine physicians which
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31 found that they correctly answered 43% of the questions regarding the U.S. Food and Drug
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33 Administration approval process.³⁴ They are also consistent with a study of physician
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35 knowledge of central line-associated blood stream infection quality metrics that found that they
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37 answered 61% of the questions correctly.³⁵
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43 In terms of Donabedian's model, the average number of correct answers was 4.7 (SD,
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45 1.50), 67% correct. This set of questions contained the easiest question, namely, whether “The
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47 percentage of patients who are satisfied with their care” was a structure, process, or outcome
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49 measure. Ninety-six percent of the physicians correctly answered that it was an outcome. The
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51 physicians were highly accurate on classifying nosocomial infections, 89%, and staffing, 84%,
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53 but they were only 53% correct in classifying beta-blockers, 53% correct in classifying
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Physician safety & quality knowledge

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3 credentials, 50% correct in classifying the diabetic foot exam, and 45% correct in classifying
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5 discharge instructions.
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8 In terms of common safety and quality definitions, the average number of correct answers
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10 was 0.39 (SD, 0.54), 20% correct. The definitions were published 19 years ago in *To Err Is*
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12 *Human*. Despite the high visibility of *To Err Is Human*, only 33% of the physicians correctly
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14 identified the IOM definition of quality. Only six percent of physicians knew the correct
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16 definition of safety.
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19 20 21 **Conclusions**

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24 U.S. physicians answered forty-eight percent of the safety and quality questions correctly.
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26 They performed best on questions that required little safety and quality knowledge and worst on
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28 question that required basic safety and quality knowledge. Our population was similar to the U.S.
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30 physician population in terms of specialty, gender, and age. There were no significant differences
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32 within specialty, gender, or age; although the scores of physicians over 60 years of age were
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34 slightly lower. These results are consistent with studies of physician knowledge of clinical harms
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36 and benefits,³² radiology knowledge,³³ knowledge of the FDA approval process,³⁴ and of
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38 quality metrics.³⁵
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42 Physicians want to practice safe, high quality medicine,³⁶ but they may not be aware of
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44 how much they need to know about safety and quality. Furthermore, physicians need time to
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46 learn about safety and quality, and they need the time and expertise required to use the
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48 information in their EHRs to monitor the safety and quality of their practice. Although many
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50 health care systems consider themselves to be healthcare learning systems,^{37,38} that belief does
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Physician safety & quality knowledge

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3 not always translate into their assisting frontline clinicians in improving their safety and quality
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5 knowledge.^{39,40}
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8 The main limitation of this study is that, although the questions were designed to assess
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10 enduring information, the two clinical questions and the two definitions may be outdated,
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12 resulting in 20 follow-up testing questions. Another limitation is that we may have overestimated
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14 physician knowledge because it used multiple-choice questions that probe recognition. Physician
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16 scores might have been substantially lower had they been asked to recall the correct answer to
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18 each question.
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22 In conclusion, forty-eight percent of the physicians' answers to the safety and quality
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24 questions were correct. A national system has been put in place at the resident level to improve
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26 physician safety and quality knowledge. Since knowledge is a prerequisite for performance, we
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28 expect that in the future physicians' increased knowledge will result in their improving their
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30 safety and quality performance. We believe this to be the first prospective test of the safety and
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32 quality knowledge of practicing U.S. primary care physicians.
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Physician safety & quality knowledge

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Figure legends

Figure 1. Percentage of subjects answering the questions correctly

Figure 2. An integrated view of the mean percent correct for each of the five topic domains

For peer review only

Physician safety & quality knowledge

Table 1. Physician characteristics^a

	Study population Number and Percent	National population Percent
Medical Specialty^b		
Family Medicine	280 (54%)	53%
Internal Medicine	238 (46%)	47%
Gender^c		
Male	331 (64%)	66%
Female	187 (36%)	34%
Age^c		
< 39	131 (25%)	21%
40 – 49	160 (31%)	24%
50 – 59	124 (24%)	24%
60 – 69	85 (17%)	20%
70 +	18 (3%)	11%

^aThere were no significant differences between the study population and the national population in terms of medical specialty, gender, or age.

^bNational: <https://www.ahrq.gov/research/findings/factsheets/primary/pcwork1/index.html>

^cNational: Young A, Chaudhry HJ, Pei X, Halbesleben K, Polk DH, Dugan M. A census of actively licensed physicians in the United States, 2014. *J Med Reg* 2015;101(2):8-23

Table 2. Questions and mean percent correct

The correct answers are in bold. The grand mean percent correct is 48%.

PATIENT MANAGEMENT: Mean percent correct = 45%

A 42-year-old female presents to your clinic for the first time. She is s/p a left lumpectomy for unilateral breast cancer. You order a BRCA test, which comes back positive for a deleterious mutation. You recommend:

Left breast mastectomy	48 (9%)
Bilateral mastectomy	166 (32%)
Bilateral salpingo-oophorectomy	8 (2%)
Left breast mastectomy and bilateral salpingo-oophorectomy	13 (3%)
Bilateral mastectomy and bilateral salpingo-oophorectomy¹²	283 (55%)

A 22-year-old female transferred to your clinic from another facility. She sees you for the first time today. She states that she has a 2 cm indeterminate renal mass that was incidentally detected during a work-up for a suspected kidney stone almost 3 years ago. Her previous physician told her that it needed to be re-imaged within 3 years. She does not remember what imaging test was used to detect the mass. She denies any new symptoms or blood in her urine. She is here for an imaging test. Pick the best test.

Arteriography kidney	1 (0%)
CT abdomen with and without contrast	114 (22%)
MRI abdomen without contrast	13 (3%)
X-ray intravenous urography	4 (1%)
CT abdomen without contrast	42 (8%)
MRI abdomen with and without contrast	32 (6%)
U/S kidney retroperitoneal with Doppler¹³	239 (46%)
CT abdomen with contrast	73 (14%)

A retired 66-year-old man presents to your clinic for a routine physical examination. He has a history of COPD. You ask about his tobacco history and he tells you that he started smoking when he was 25 years old, he smoked 1 pack-per-day for 25 years, and he stopped smoking when he was 50 years old. He wants to know if he should do something to assess his risk of lung cancer. You order:

No imaging¹⁴	173 (33%)
Chest x-ray, PA and lateral	72 (14%)
CT of the chest without contrast	35 (7%)
CT of the chest with and without contrast	16 (3%)
A low-dose CT of the chest	222 (43%)

RADIATION RISK: Mean percent correct = 40%

The effective dose of a two-view chest radiograph is approximately:

0.01 mSv (millisievert)	62 (12%)
0.1 mSv¹⁵	316 (61%)
1.0 mSv	112 (22%)
10.0 mSv	28 (5%)

The effective dose of a two-view mammogram is approximately:

0.04 mSv (millisievert)	116 (22%)
0.4 mSv¹⁶	313 (60%)
4.0 mSv	84 (16%)
40.0 mSv	5 (1%)

The effective dose of a single CT of the abdomen and pelvis, with and without contrast is approximately:

0.02 mSv (millisievert)	9 (2%)
0.2 mSv	69 (13%)
2.0 mSv	206 (40%)
20.0 mSv¹⁷	234 (45%)

For the average American living at sea level, the annual effective dose of radiation is approximately:

0.03 mSv (millisievert)	223 (43%)
0.3 mSv	148 (29%)
3.0 mSv¹⁸	127 (25%)
30.0 mSv	20 (4%)

Receiving at least 20 mSv (millisieverts) of radiation increases an adult person's risk of a fatal cancer by approximately:

1 in 100,000 – 1,000,000	116 (22%)
1 in 10,000 – 100,000	183 (35%)
1 in 1,000 – 10,000	164 (32%)
1 in 100 – 1,000¹⁹	55 (11%)

GENERAL SAFETY AND QUALITY: Mean percent correct 45%

The main hospital accreditation body in the United States is:

Institute for Healthcare Improvement (IHI)	2 (0%)
American Hospital Association (AHA)	16 (3%)

Physician safety & quality knowledge

National Committee for Quality Assurance (NCQA)	27 (5%)
The Joint Commission (JC)²⁰	456 (88%)
Centers for Medicare and Medicaid Services (CMS)	17 (3%)

Which one of the following refers to acting in the best interest of the patient?

Respect for autonomy	60 (12%)
Beneficence²¹	382 (74%)
Nonmaleficence	62 (12%)
Justice	5 (1%)
Fairness	9 (2%)

Which of the following is the correct description of the Swiss cheese model of accidents?

Many people making the same mistake over and over again will eventually cause an accident.	65 (13%)
It usually takes several things going wrong for an accident to happen.²²	274 (53%)
If a person makes the same mistake many times, it will eventually cause an accident.	57 (11%)
It is about filling in holes in the system.	108 (21%)
A person who makes a root cause error will cause an accident.	14 (3%)

Select from the list below the method that is NOT a tool for analyzing quality improvement.

Process mapping	20 (4%)
Flow charts	58 (11%)
Fishbone diagrams	127 (25%)
Discharge checklists²³	177 (34%)
Pareto charts	136 (26%)

Which of the following is NOT a part of “6-sigma?”

Its goal is to reduce errors to a rate of 3.4 errors per million opportunities to make an error.	66 (13%)
It involves a series of five steps: define, measure, analyze, improve, and control.	93 (18%)
It is especially useful for processes that do not happen frequently.²⁴	99 (19%)
Its practitioners are known as black belts.	165 (32%)
It is six standard deviations from the average.	95 (18%)

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The most frequent reason for hospital medication errors is:

Prescribing²⁵	98 (19%)
Transcribing	244 (47%)
Dispensing	64 (12%)
Administration	93 (18%)
Monitoring	19 (4%)

Several methods for detecting harms are shown below. Used in their usual way, which method detects the most harms?

Direct observation of care	129 (25%)
Reports by clinicians	30 (6%)
IHI global trigger tools²⁶	73 (14%)
AHRQ Patient Safety Indicators	169 (33%)
Chart reviews	117 (23%)

STRUCTURE, PROCESS, OUTCOME: Mean percent correct = 67%

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. The percentage of patients who are satisfied with their care.

S	6 (1%)
P	17 (3%)
O²⁷	495 (96%)

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. Percentage of patients that experience a nosocomial infection.

S	18 (3%)
P	37 (7%)
O²⁷	463 (89%)

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. There is enough clinical staff to care for the patients.

S²⁷	436 (84%)
P	46 (9%)
O	36 (7%)

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. The percentage of patients with an acute myocardial infarction who receive a beta-blocker.

S	26 (5%)
P²⁷	274 (53%)

Physician safety & quality knowledge

O	218 (42%)
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Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. Clinicians are properly credentialed.

S²⁷	272 (53%)
P	226 (44%)
O	20 (4%)

Identify whether it is an example of a structure (S), process (P), or outcome (O).

Q. The percentage of diabetic patients that have an order for an annual foot exam.

S	55 (11%)
P²⁷	257 (50%)
O	206 (40%)

Identify whether this is an example of a structure (S), process (P), or outcome (O).

Q. The percentage of patients that are given discharge instructions.

S	12 (2%)
P²⁷	234 (45%)
O	272 (53%)

QUALITY AND SAFETY DEFINITIONS: Mean percent correct = 48%

The Institute of Medicine's definition of quality is:

Providing acceptable and expected medical care, where acceptable means medical care that patients understand, agree to, and can afford, and expected means performance at the current professional standard of care.	183 (35%)
Doing the right thing at the right time for the right individual to get the best possible results.	75 (14%)
The degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge.²⁸	170 (33%)
A system in which organizations are accountable for continuously improving the quality of their services and safeguarding high standards of care.	65 (13%)
Receiving the best care possible for one's illness or condition.	25 (5%)

The Institute of Medicine's definition of safety is:

The minimization of the risk of any harm, and the amelioration of the effect of a harm, to a person caused by medical care.	135 (26%)
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Physician safety & quality knowledge

Freedom from accidental or preventable injuries produced by medical care.	60 (12%)
Assuring that all care is safe for all patients requires examining the systems and processes of care, identifying the points of failure, and modifying the factors that cause systems to break down.	90 (17%)
The avoidance, prevention, and amelioration of adverse outcomes or injuries stemming from the process of care.	200 (39%)
Freedom from accidental injury, where accidental injury can be due to error, as either the failure of a planned action to be completed as intended or the use of the wrong plan to achieve an aim.²⁹	33 (6%)

Figure 1. Percentage of subjects answering the questions correctly

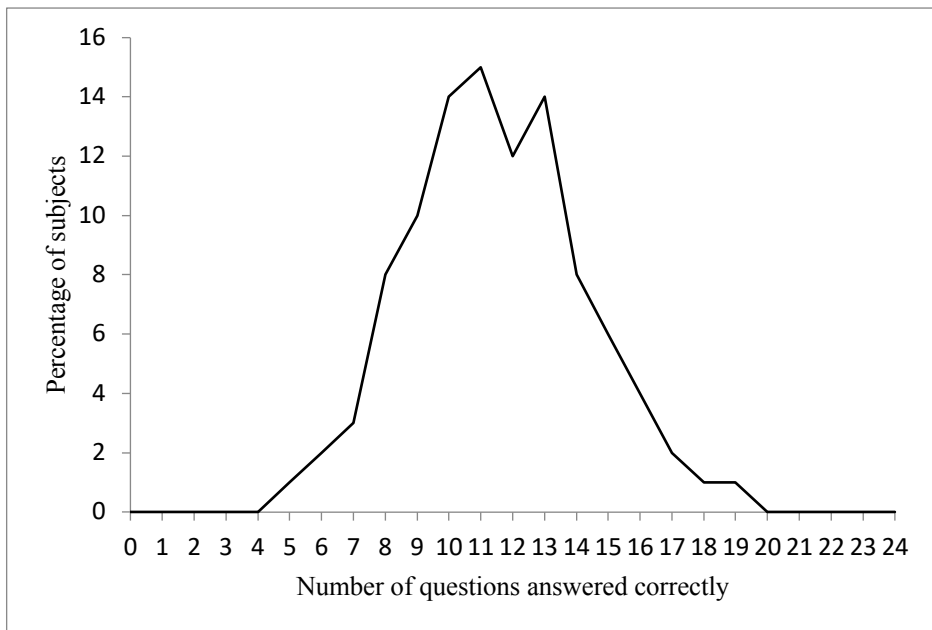
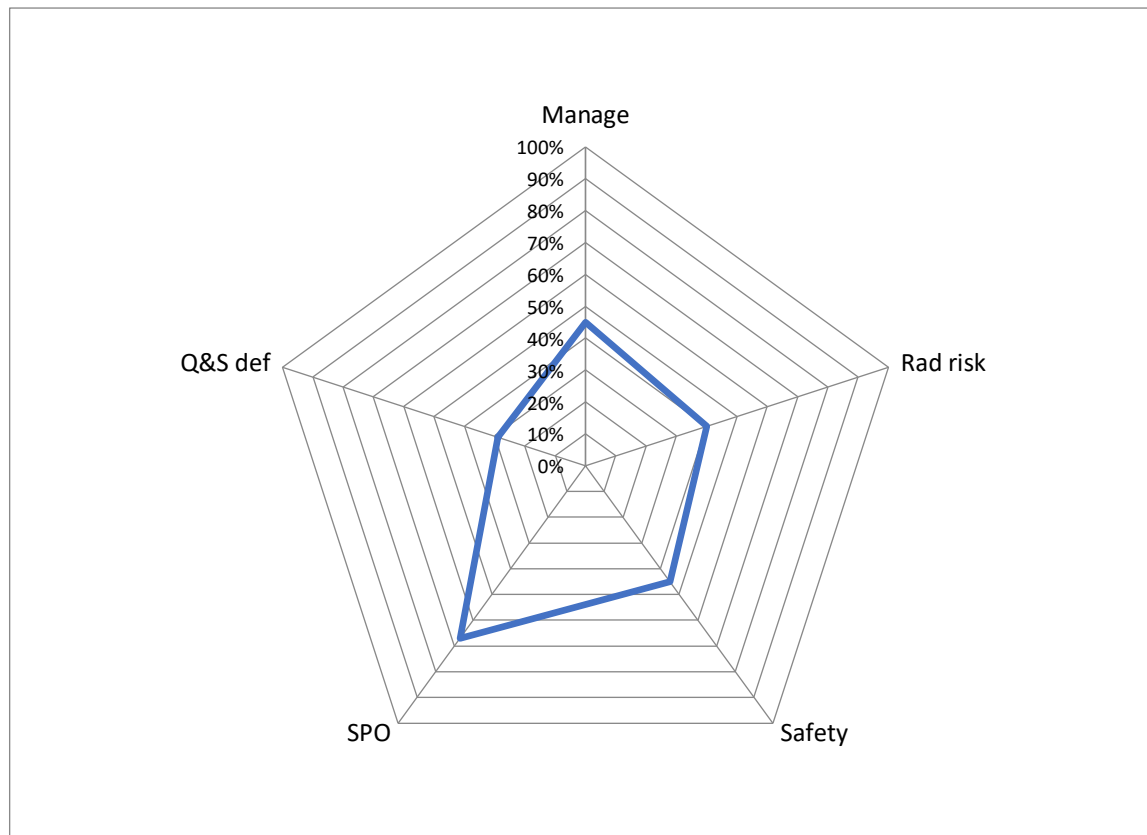


Figure 2. An integrated view of the mean percent correct for each of the five topic domains



BMJ Open

Original research: Responses of physicians to an objective safety and quality knowledge test: a cross-sectional study

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Keywords:	Quality in health care < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health & safety < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, MEDICAL EDUCATION & TRAINING

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Physician safety & quality knowledge

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62 57 high reliability, healthcare organization
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Abstract**Objective**

It is well known that, for physicians to practice safe, high quality medicine, they must have sufficient safety and quality knowledge. Although a great deal is known about the safety and quality perceptions, attitudes, and beliefs of physicians, little is known about their safety and quality knowledge. This study tested the safety and quality knowledge of practicing primary care physicians.

Design

Cross-sectional objective test of safety and quality knowledge

Setting

Primary care physicians practicing in the United States.

Participants

Study consisted of 518 U.S. practicing primary care physicians who answered an email invitation. It included 54% Family Medicine and 46% Internal Medicine physicians, who accepted an email invitation. The response rate was 66%.

Intervention

The physicians took a 24-question multiple-choice test over the Internet.

Outcome

The outcome was the percent correct.

Results

The average number of correct answers was 11.4 (SD, 2.69), 48% correct. Three common clinical vignettes questions were answered correctly by 45% of the physicians. Five physicians' knowledge of common radiation exposures questions were answered correctly by 40% of the physicians. Seven common healthcare quality and safety questions were answered correctly by 43% of the physicians. Seven Donabedian's model of structure, process, and outcome measure questions were answered correctly by 67% of the physicians. Two Institute of Medicine's definitions of quality and safety questions were answered correctly by 19.5% of the physicians.

Conclusion

Forty-eight percent of the physicians' answers to the safety and quality questions were correct. To our knowledge, this is the first assessment of the safety and quality knowledge of practicing U.S. primary care physicians.

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Strengths and limitations of this study

- A strength is that it consisted of practicing primary care physicians
- A strength is that it is representative of U.S. physicians
- A strength is its large sample size
- A limitation is that there is no conical safety and quality corpus.

Introduction

The landmark Institute of Medicine (IOM) report, *To Err Is Human: Building a Safer Health System*,¹ described a medical system that had become a clinical colossus, but its safety and quality had not kept pace with its size and complexity. It presented a system that was committing more errors yet detecting and correcting only a small fraction of them. It described a system with significant safety and quality deficits, some of which resulted in patient injury and death, and it recommended sweeping healthcare reforms.

Since *To Err Is Human* was published more than 20 years ago, a great deal of work has been done on improving safety and quality,² yet a recent IOM report, *Best Care at Lower Cost: The Path to Continuously Learning Health Care in America*,³ and a recent study,⁴ suggest that many of the errors reported in *To Err Is Human* are continuing. The persistence and frequency of errors, and our reduced tolerance for errors, has heightened the importance³ in medical safety and quality.

Although a great deal is known about the safety and quality perceptions, attitudes, opinions, and beliefs of physicians,⁵⁻⁹ little is known about their safety and quality knowledge. We designed a cross-sectional test of the safety and quality knowledge of practicing physicians.

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122 We believe this to be the first test of the safety and quality knowledge of practicing U.S. primary
123 care physicians.

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125 Methods

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127 This is a cross-sectional one-time test of the safety and quality knowledge of practicing
128 United States (U.S.) General Internal Medicine and Family Medicine physicians. Its participants
129 were drawn from a national panel of physicians registered in Medscape. Physicians who
130 completed the test received a \$30.00 Amazon gift card. The test was budgeted for 518 physicians
131 completing the test. Seven hundred and eighty-eight practicing primary care physicians were
132 randomly selected and solicited via email, which resulted in a 66% response rate. The test
133 instrument was web-based and consisted of 24 multiple-choice questions. The objective
134 questions were taken from widely available safety and quality textbooks and clinical literature
135 and they were designed to reflect the practical safety and quality knowledge of practicing
136 physicians. There were six areas of questions: patient management, radiation risk, general safety
137 and quality, structure, process and outcome; and quality and safety definitions.

138 In terms of patient management, three common patient management vignettes addressed
139 the physician's clinical quality knowledge. For the breast cancer vignette, there were five
140 possible answers.¹⁰ For the renal mass, the American College of Radiology (ACR)
141 Appropriateness Criteria¹¹ gave the computed tomography (CT) abdomen without and with
142 intravenous (IV) contrast the highest appropriateness rating, 9, but this modality also had the
143 highest radiation level. The ultrasound kidney retroperitoneal with duplex Doppler had the next
144 highest rating, 8. The ACR states that appropriateness ratings of 9, 8, and 7 are "Usually

Physician safety & quality knowledge

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3 145 appropriate.” There were eight possible answers to the renal mass question. ¹² Finally, in terms of
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5 146 patient management, the lung cancer screening consisted of five possible answers. ¹³
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8 147 In terms of common radiation risks, five questions addressed physicians’ knowledge of
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10 148 common radiation risks. ¹⁴⁻¹⁸ There were four choices per question, each choice differed by one
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12 149 base-ten log. In other words, the four possible answers to the question spanned a four-log range.
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15 150 In terms of common healthcare system safety and quality issues, there were seven
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17 151 questions. ¹⁹⁻²⁵ There were five choices per question. In terms of Donabedian’s ²⁶ model for
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19 152 assessing safety and quality in terms of structure, process, and outcomes, there were seven
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21 153 questions. There were three choices per question. Two questions asked physicians to identify
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23 154 common quality ²⁷ and safety ²⁸ definitions from the IOM. There were five choices per question.
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25 155 The most difficult of the 24 questions was the IOM’s definition of safety. Limiting the definition
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27 156 to “freedom from accidental injury,” would not have distinguished it from other safety
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29 157 definitions. Therefore, the correct answer included the rest of the IOM definition, “where
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31 158 accidental injury can be due to error, as either the failure of a planned action to be completed as
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33 159 intended or the use of the wrong plan to achieve an aim.”
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38 160 The questions and answers are shown in Table 1. The questions were presented in a
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40 161 random order and no changes were made to the questions during testing. The only instruction the
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42 162 physicians received was that they had to answer all the questions. The deidentified results were
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44 163 sent to the investigators by Medscape. The questions were not weighted. For each question, the
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46 164 percent correct is calculated and, for each topic, the average percent correct was calculated. The
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48 165 Chi-square test was used to assess demographic differences and whether the categorial answer
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50 166 frequencies differed from chance, and the Student’s t-test was used to compare continuous
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53 167 variables. The tests were performed using R (www.R-project.org) and significance was set at a
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3 168 probability of less than 0.05. The Uniformed Services University Institutional Review Board
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5 169 approved this research. There was no patient or public involvement.
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10 171 **Results**

12 172 The study demographics of the 518 physicians are shown in Table 2. The medical
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14 173 specialty of the participants was 46% General Internal Medicine and 54% Family Medicine. The
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16 174 gender of the participants was 64% male and 35% female. There were no significant differences
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18 175 between the participants and practicing physicians in terms of specialty, gender, and age.^{29,30}
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20 176 There were no significant differences in the test scores within specialty, gender, and age, except
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22 177 for slightly lower scores for physicians over 60 years of age compared to those under 60 years of
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24 178 age, 0.45 (SD, 0.12) and 0.48 (SD, 0.11) respectively, $p = 0.003$. The median time to take the test
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26 179 was 10.1 minutes.
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31 180 The results are shown in Table 1. The average number of correct answers was 11.4 (SD,
32
33 181 2.69), 48% correct. Every physician answered at least four questions correctly and no physician
34
35 182 answered more than 20 questions correctly (Figure 1). For each question, the distribution of
36
37 183 answers was significantly different from that expected by chance ($p < 0.01$). The mean percent
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39 184 correct for each of the five topics is shown in Figure 2.
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42 185 In terms of the three common management vignettes, the average number of correct
43
44 186 answers was 1.3 (SD, 0.90), 45% correct. For the breast cancer vignette, fifty-five percent of the
45
46 187 physicians knew how to manage a woman with breast cancer who tested positive for a
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48 188 deleterious BRCA mutation. For the renal mass vignette, 46%, knew the work up for an
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50 189 indeterminate renal mass. For the lung cancer screening, 33%, knew the current approach to
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52 190 screening for lung cancer. Forty-six percent of the physicians correctly balanced the radiation
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Physician safety & quality knowledge

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3 191 risk against the marginal additional benefit of CT and chose the ultrasound test. These results are
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5 192 also consistent with a recent study that found that physicians rarely have accurate expectations of
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8 193 the harms and benefits of clinical interventions, which the investigators attributed to a lack of
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10 194 knowledge.³¹

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12 195 In terms of common radiation risks, the average number of correct answers was 2.0 (SD,
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14 196 1.14), 40% correct. Sixty-one percent of the physicians correctly identified the radiation
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16 197 exposure delivered by a chest x-ray, 60% correctly identified the radiation exposure delivered by
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18 198 a mammogram, but only 45%, could correctly identify the radiation exposure delivered by a CT
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20 199 scan of the abdomen and pelvis. Furthermore, in terms of population risk, only 25% of the
21
22 200 physicians correctly chose the annual natural radiation exposure of an individual and only 11%
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24 201 knew the degree to which a 20 mSv of radiation exposure increased the population risk of a fatal
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26 202 cancer. These results are consistent with a systematic review of computed tomography and other
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28 203 radiographic procedures that found a similarly low level of radiology exposure knowledge
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31 204 among physicians.³²

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33 205 In terms of commons healthcare system safety and quality issues, the average number of
34
35 206 correct answers was 3.0 (SD, 1.27), 43% correct. Eighty-eight percent of the physicians knew the
36
37 207 main hospital accrediting body, 74% knew the definition of beneficence, and 53% knew the
38
39 208 Swiss Cheese model of accidents. But their accuracy was lower for questions regarding quality
40
41 209 improvement tools, medication errors, 6-sigma, and harm detection – which were answered
42
43 210 correctly by 34%, 19%, 19%, and 14% of the physicians, respectively. These results are
44
45 211 consistent with a recent study of generalist and subspecialist Internal Medicine physicians which
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47 212 found that they correctly answered 43% of the questions regarding the U.S. Food and Drug
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49 213 Administration approval process.³³ They are also consistent with a study of physician
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Physician safety & quality knowledge

214 knowledge of central line-associated blood stream infection quality metrics that found that they
215 answered 61% of the questions correctly.³⁴

216 In terms of Donabedian's model, the average number of correct answers was 4.7 (SD,
217 1.50), 67% correct. This set of questions contained the easiest question, namely, whether "The
218 percentage of patients who are satisfied with their care" was a structure, process, or outcome
219 measure. Ninety-six percent of the physicians correctly answered that it was an outcome. The
220 physicians were highly accurate on classifying nosocomial infections, 89%, and staffing, 84%,
221 but they were only 53% correct in classifying beta-blockers, 53% correct in classifying
222 credentials, 50% correct in classifying the diabetic foot exam, and 45% correct in classifying
223 discharge instructions.

224 In terms of common safety and quality definitions, the average number of correct answers
225 was 0.39 (SD, 0.54), 20% correct. The definitions were published 19 years ago in *To Err Is*
226 *Human*. Despite the high visibility of *To Err Is Human*, only 33% of the physicians correctly
227 identified the IOM definition of quality. Only six percent of physicians knew the correct
228 definition of safety.

229 Discussion

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231
232 U.S. physicians answered forty-eight percent of the safety and quality questions correctly.
233 They performed best on questions that required little safety and quality knowledge and worst on
234 question that required basic safety and quality knowledge. Our population was similar to the U.S.
235 physician population in terms of specialty, gender, and age. There were no significant differences
236 within specialty, gender, or age; although the scores of physicians over 60 years of age were
237 slightly lower. These results are consistent with studies of physician knowledge of clinical harms

Physician safety & quality knowledge

238 and benefits,³¹ radiology knowledge,³² knowledge of the FDA approval process,³³ and of
239 quality metrics.³⁴

240 Physicians want to practice safe, high quality medicine,³⁵ but they may not be aware of
241 how much they need to know about safety and quality. Furthermore, physicians need time to
242 learn about safety and quality, and they need the time and expertise required to use the
243 information in their EHRs to monitor the safety and quality of their practice. Although many
244 health care systems consider themselves to be healthcare learning systems,^{36,37} that belief does
245 not always translate into their assisting frontline clinicians in improving their safety and quality
246 knowledge.^{38,39}

247 The main limitation of this study is that there is no canonical safety and quality corpus.
248 Another limitation is that we may have overestimated physician knowledge because it used
249 multiple-choice questions that probe recognition. Physician scores might have been substantially
250 lower had they been asked to recall the correct answer to each question.

252 Conclusions

253 Only forty-eight percent of the physicians' answers to the safety and quality questions
254 were correct. A national system has been put in place at the resident level to improve physician
255 safety and quality knowledge. Since knowledge is a prerequisite for performance, we expect that
256 future physicians' increased knowledge will result in less patient harm and improved clinical
257 outcomes. We believe this to be the first prospective test of the safety and quality knowledge of
258 practicing U.S. primary care physicians.

259

Author contributions

HB: originated the study idea and designed the research project, analyzed the study data and drafted the manuscript. HK: made important contributions to designing the research project and analyzing the study data, and made significant contributions to the writing of the manuscript.

Conflicting and/or competing interests

The authors declare that they have no conflicts or competing interests.

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Ethics Approval

This study was approved by the Uniformed Services University of the Health Sciences IRB.

Patient and public involvement

There was no patient or public involvement in this study.

Data sharing

The frequency counts for each question are provided.

Disclaimer

The findings and conclusions of this paper are those of the authors and do not necessarily represent the positions or views of the U.S. Department of Defense, the Military Health System, the Defense Health Agency, or the Uniformed Services University of the Health Sciences.

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None.

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Figure legends

Figure 1. Percentage of subjects answering the questions correctly

Figure 2. An integrated view of the mean percent correct for each of the five topic domains

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3 **433 Table 1. Questions and mean percent correct**

4 434

5 435 The correct answers are in bold. The grand mean percent correct is 48%.

6 436

7 **437 PATIENT MANAGEMENT: Mean percent correct = 45%**

8 438

9 439 A 42-year-old female presents to your clinic for the first time. She is s/p a left lumpectomy for
10 440 unilateral breast cancer. You order a BRCA test, which comes back positive for a deleterious
11 441 mutation. You recommend:

Left breast mastectomy	48 (9%)
Bilateral mastectomy	166 (32%)
Bilateral salpingo-oophorectomy	8 (2%)
Left breast mastectomy and bilateral salpingo-oophorectomy	13 (3%)
Bilateral mastectomy and bilateral salpingo-oophorectomy	283 (55%)

12 442

13 443 A 22-year-old female transferred to your clinic from another facility. She sees you for the first
14 444 time today. She states that she has a 2 cm indeterminate renal mass that was incidentally detected
15 445 during a work-up for a suspected kidney stone almost 3 years ago. Her previous physician told
16 446 her that it needed to be re-imaged within 3 years. She does not remember what imaging test was
17 447 used to detect the mass. She denies any new symptoms or blood in her urine. She is here for an
18 448 imaging test. Pick the best test.

Arteriography kidney	1 (0%)
CT abdomen with and without contrast	114 (22%)
MRI abdomen without contrast	13 (3%)
X-ray intravenous urography	4 (1%)
CT abdomen without contrast	42 (8%)
MRI abdomen with and without contrast	32 (6%)
U/S kidney retroperitoneal with Doppler	239 (46%)
CT abdomen with contrast	73 (14%)

19 449

20 450 A retired 66-year-old man presents to your clinic for a routine physical examination. He has a
21 451 history of COPD. You ask about his tobacco history and he tells you that he started smoking
22 452 when he was 25 years old, he smoked 1 pack-per-day for 25 years, and he stopped smoking
23 453 when he was 50 years old. He wants to know if he should do something to assess his risk of lung
24 454 cancer. You order:

No imaging	173 (33%)
Chest x-ray, PA and lateral	72 (14%)
CT of the chest without contrast	35 (7%)
CT of the chest with and without contrast	16 (3%)
A low-dose CT of the chest	222 (43%)

25 455

26 456

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3 457 **RADIATION RISK: Mean percent correct = 40%**

4 458

5 459 The effective dose of a two-view chest radiograph is approximately:

0.01 mSv (millisievert)	62 (12%)
0.1 mSv	316 (61%)
1.0 mSv	112 (22%)
10.0 mSv	28 (5%)

13 460

14 461 The effective dose of a two-view mammogram is approximately:

0.04 mSv (millisievert)	116 (22%)
0.4 mSv	313 (60%)
4.0 mSv	84 (16%)
40.0 mSv	5 (1%)

21 462

22 463 The effective dose of a single CT of the abdomen and pelvis, with and without contrast is
23 464 approximately:

0.02 mSv (millisievert)	9 (2%)
0.2 mSv	69 (13%)
2.0 mSv	206 (40%)
20.0 mSv	234 (45%)

30 465

31 466 For the average American living at sea level, the annual effective dose of radiation is
32 467 approximately:

0.03 mSv (millisievert)	223 (43%)
0.3 mSv	148 (29%)
3.0 mSv	127 (25%)
30.0 mSv	20 (4%)

39 468

40 469 Receiving at least 20 mSv (millisieverts) of radiation increases an adult person's risk of a fatal
41 470 cancer by approximately:

1 in 100,000 – 1,000,000	116 (22%)
1 in 10,000 – 100,000	183 (35%)
1 in 1,000 – 10,000	164 (32%)
1 in 100 – 1,000	55 (11%)

48 471

49 472 **GENERAL SAFETY AND QUALITY: Mean percent correct 45%**

50 473

51 474 The main hospital accreditation body in the United States is:

Institute for Healthcare Improvement (IHI)	2 (0%)
American Hospital Association (AHA)	16 (3%)

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National Committee for Quality Assurance (NCQA)	27 (5%)
The Joint Commission (JC)	456 (88%)
Centers for Medicare and Medicaid Services (CMS)	17 (3%)

475

476

Which one of the following refers to acting in the best interest of the patient?

Respect for autonomy	60 (12%)
Beneficence	382 (74%)
Nonmaleficence	62 (12%)
Justice	5 (1%)
Fairness	9 (2%)

477

478

Which of the following is the correct description of the Swiss cheese model of accidents?

Many people making the same mistake over and over again will eventually cause an accident.	65 (13%)
It usually takes several things going wrong for an accident to happen.	274 (53%)
If a person makes the same mistake many times, it will eventually cause an accident.	57 (11%)
It is about filling in holes in the system.	108 (21%)
A person who makes a root cause error will cause an accident.	14 (3%)

479

480

Select from the list below the method that is NOT a tool for analyzing quality improvement.

Process mapping	20 (4%)
Flow charts	58 (11%)
Fishbone diagrams	127 (25%)
Discharge checklists	177 (34%)
Pareto charts	136 (26%)

481

482

Which of the following is NOT a part of "6-sigma"?

Its goal is to reduce errors to a rate of 3.4 errors per million opportunities to make an error.	66 (13%)
It involves a series of five steps: define, measure, analyze, improve, and control.	93 (18%)
It is especially useful for processes that do not happen frequently.	99 (19%)
Its practitioners are known as black belts.	165 (32%)
It is six standard deviations from the average.	95 (18%)

483

484

485

486 The most frequent reason for hospital medication errors is:

Prescribing	98 (19%)
Transcribing	244 (47%)
Dispensing	64 (12%)
Administration	93 (18%)
Monitoring	19 (4%)

487
488 Several methods for detecting harms are shown below. Used in their usual way, which
489 method detects the most harms?

Direct observation of care	129 (25%)
Reports by clinicians	30 (6%)
IHI global trigger tools	73 (14%)
AHRQ Patient Safety Indicators	169 (33%)
Chart reviews	117 (23%)

490
491 **STRUCTURE, PROCESS, OUTCOME: Mean percent correct = 67%**

492
493 Identify whether this is an example of a structure (S), process (P), or outcome (O).

494 Q. The percentage of patients who are satisfied with their care.

S	6 (1%)
P	17 (3%)
O	495 (96%)

495
496 Identify whether this is an example of a structure (S), process (P), or outcome (O).

497 Q. Percentage of patients that experience a nosocomial infection.

S	18 (3%)
P	37 (7%)
O	463 (89%)

498
499 Identify whether this is an example of a structure (S), process (P), or outcome (O).

500 Q. There is enough clinical staff to care for the patients.

S	436 (84%)
P	46 (9%)
O	36 (7%)

501
502 Identify whether this is an example of a structure (S), process (P), or outcome (O).

503 Q. The percentage of patients with an acute myocardial infarction who receive a beta-blocker.

S	26 (5%)
P	274 (53%)

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O	218 (42%)
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504

505 Identify whether this is an example of a structure (S), process (P), or outcome (O).

506 Q. Clinicians are properly credentialed.

S	272 (53%)
P	226 (44%)
O	20 (4%)

507

508

509 Identify whether it is an example of a structure (S), process (P), or outcome (O).

510 Q. The percentage of diabetic patients that have an order for an annual foot exam.

S	55 (11%)
P	257 (50%)
O	206 (40%)

511

512 Identify whether this is an example of a structure (S), process (P), or outcome (O).

513 Q. The percentage of patients that are given discharge instructions.

S	12 (2%)
P	234 (45%)
O	272 (53%)

514

515

516 **QUALITY AND SAFETY DEFINITIONS: Mean percent correct = 48%**

517

518

The Institute of Medicine's definition of quality is:

Providing acceptable and expected medical care, where acceptable means medical care that patients understand, agree to, and can afford, and expected means performance at the current professional standard of care.	183 (35%)
Doing the right thing at the right time for the right individual to get the best possible results.	75 (14%)
The degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge.	170 (33%)
A system in which organizations are accountable for continuously improving the quality of their services and safeguarding high standards of care.	65 (13%)
Receiving the best care possible for one's illness or condition.	25 (5%)

519

520 The Institute of Medicine's definition of safety is:

The minimization of the risk of any harm, and the amelioration of the effect of a harm, to a person caused by medical care.	135 (26%)
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Physician safety & quality knowledge

Freedom from accidental or preventable injuries produced by medical care.	60 (12%)
Assuring that all care is safe for all patients requires examining the systems and processes of care, identifying the points of failure, and modifying the factors that cause systems to break down.	90 (17%)
The avoidance, prevention, and amelioration of adverse outcomes or injuries stemming from the process of care.	200 (39%)
Freedom from accidental injury, where accidental injury can be due to error, as either the failure of a planned action to be completed as intended or the use of the wrong plan to achieve an aim.	33 (6%)

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Physician safety & quality knowledge

525 **Table 2. Physician characteristics^a**

526

	Study population Number and Percent	National population Percent
Medical Specialty^b		
Family Medicine	280 (54%)	53%
Internal Medicine	238 (46%)	47%
Gender^c		
Male	331 (64%)	66%
Female	187 (36%)	34%
Age^c		
< 39	131 (25%)	21%
40 – 49	160 (31%)	24%
50 – 59	124 (24%)	24%
60 – 69	85 (17%)	20%
70 +	18 (3%)	11%

^aThere were no significant differences between the study population and the national population in terms of medical specialty, gender, or age.

^bNational: <https://www.ahrq.gov/research/findings/factsheets/primary/pcwork1/index.html>

^cNational: Young A, Chaudhry HJ, Pei X, Halbesleben K, Polk DH, Dugan M. A census of actively licensed physicians in the United States, 2014. *J Med Reg* 2015;101(2):8-23

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Figure 1. Percentage of subjects answering the questions correctly

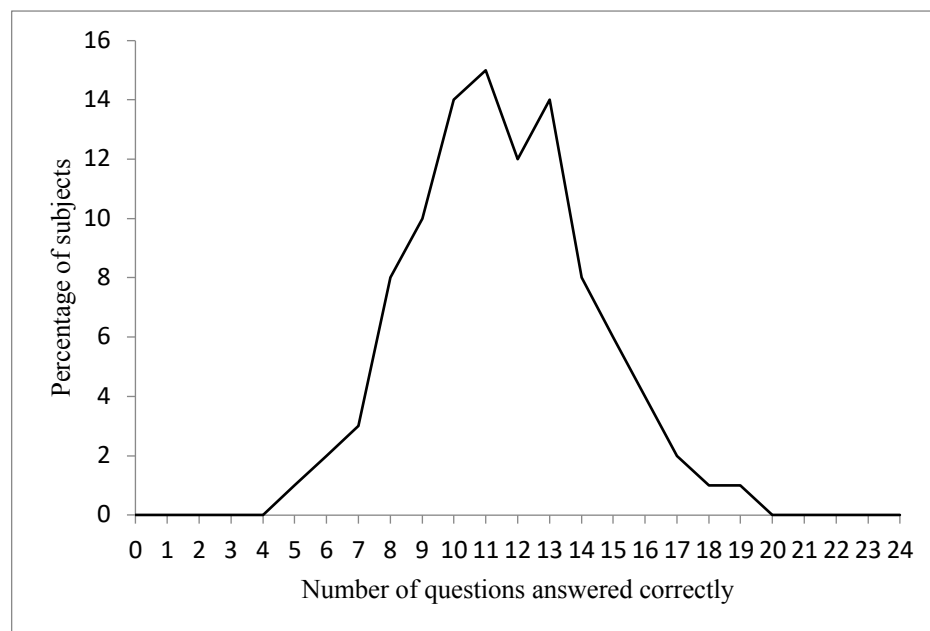
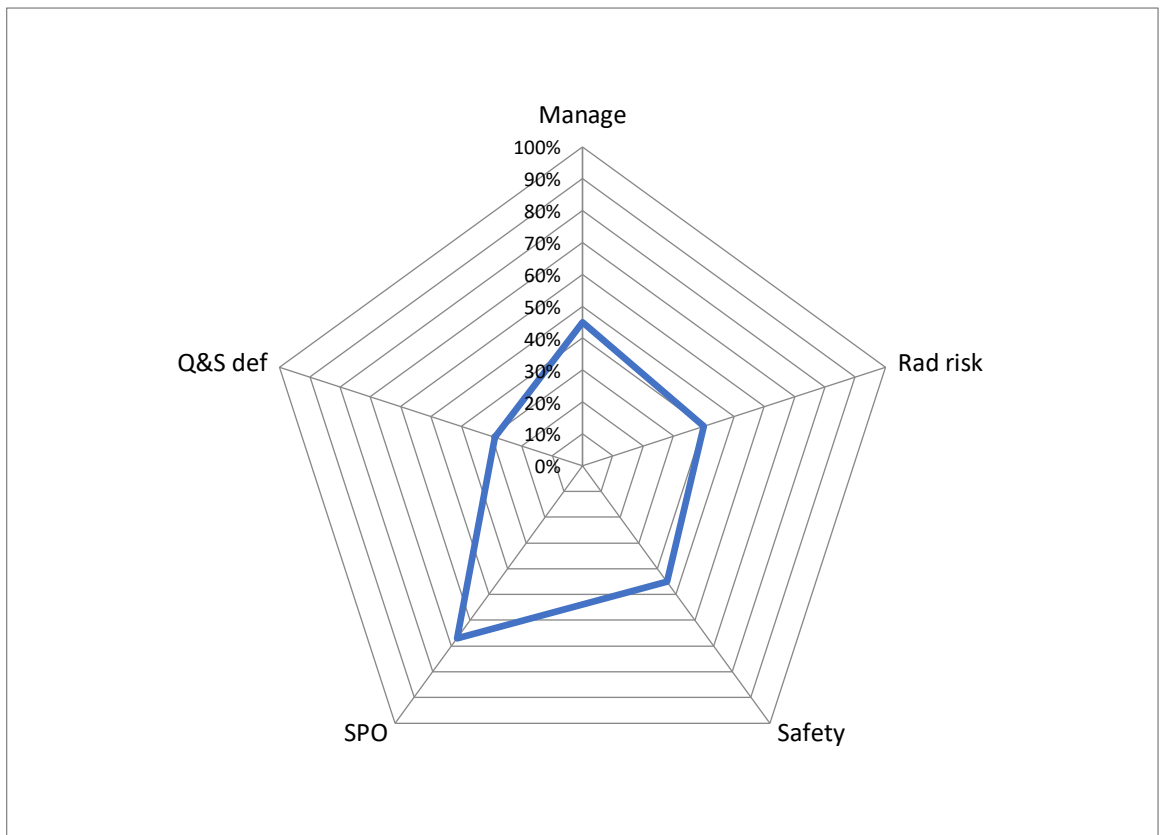


Figure 2. An integrated view of the mean percent correct for each of the five topic domains



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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
P1L4		(b) Provide in the abstract an informative and balanced summary of what was done
P2		and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
P4L4-20		
Objectives	3	State specific objectives, including any prespecified hypotheses
P4L16-20		
Methods		
Study design	4	Present key elements of study design early in the paper
P5L1-2		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
P5L1-11		
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants
P5L1-3		
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
P5L12-23, P6L1-10		
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
P5L7-10		
Bias	9	Describe any efforts to address potential sources of bias
P5L2-3		
Study size	10	Explain how the study size was arrived at
P5L4-6		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
P6L14-19		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding
P6L14-19		(b) Describe any methods used to examine subgroups and interactions
		(c) Explain how missing data were addressed
		(d) If applicable, describe analytical methods taking account of sampling strategy
		(e) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
P7L1		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
P7L2-7		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15*	Report numbers of outcome events or summary measures
P7-9		
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were
P7-9		

		adjusted for and why they were included
		(b) Report category boundaries when continuous variables were categorized
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses NA	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results P9L15-22	18	Summarise key results with reference to study objectives
Limitations P10L6-9	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation P10L12-17	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability P10L13-16	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding P3L14	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Responses of physicians to an objective safety and quality knowledge test: a cross-sectional study

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Physician safety & quality knowledge

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Abstract**Objective**

It is well known that, for physicians to practice safe, high quality medicine, they must have sufficient safety and quality knowledge. Although a great deal is known about the safety and quality perceptions, attitudes, and beliefs of physicians, little is known about their safety and quality knowledge. This study tested the safety and quality knowledge of practicing primary care physicians.

Design

Cross-sectional objective test of safety and quality knowledge

Setting

Primary care physicians practicing in the United States.

Participants

Study consisted of 518 U.S. practicing primary care physicians who answered an email invitation. It included 54% Family Medicine and 46% Internal Medicine physicians, who accepted an email invitation. The response rate was 66%.

Intervention

The physicians took a 24-question multiple-choice test over the Internet.

Outcome

The outcome was the percent correct.

Results

The average number of correct answers was 11.4 (SD, 2.69), 48% correct. Three common clinical vignettes questions were answered correctly by 45% of the physicians. Five physicians' knowledge of common radiation exposures questions were answered correctly by 40% of the physicians. Seven common healthcare quality and safety questions were answered correctly by 43% of the physicians. Seven Donabedian's model of structure, process, and outcome measure questions were answered correctly by 67% of the physicians. Two Institute of Medicine's definitions of quality and safety questions were answered correctly by 19.5% of the physicians.

Conclusion

Forty-eight percent of the physicians' answers to the safety and quality questions were correct. To our knowledge, this is the first assessment of the safety and quality knowledge of practicing U.S. primary care physicians.

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Strengths and limitations of this study

- A strength is that it consisted of practicing primary care physicians
- A strength is that it is representative of U.S. physicians
- A strength is its large sample size
- A limitation is that there is no canonical safety and quality corpus.

Introduction

The landmark Institute of Medicine (IOM) report, *To Err Is Human: Building a Safer Health System*,¹ described a medical system that had become a clinical colossus, but its safety and quality had not kept pace with its size and complexity. It presented a system that was committing more errors yet detecting and correcting only a small fraction of them. It described a system with significant safety and quality deficits, some of which resulted in patient injury and death, and it recommended sweeping healthcare reforms.

Since *To Err Is Human* was published more than 20 years ago, a great deal of work has been done on improving safety and quality,² yet a recent IOM report, *Best Care at Lower Cost: The Path to Continuously Learning Health Care in America*,³ and a recent study,⁴ suggest that many of the errors reported in *To Err Is Human* are continuing. The persistence and frequency of errors, and our reduced tolerance for errors, has heightened the importance³ in medical safety and quality.

Although a great deal is known about the safety and quality perceptions, attitudes, opinions, and beliefs of physicians,⁵⁻⁹ little is known about their safety and quality knowledge. We designed a cross-sectional test of the safety and quality knowledge of practicing physicians.

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122 We believe this to be the first test of the safety and quality knowledge of practicing U.S. primary
123 care physicians.

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125 Methods

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127 This is a cross-sectional one-time test of the safety and quality knowledge of practicing
128 United States (U.S.) General Internal Medicine and Family Medicine physicians. Its participants
129 were drawn from a national panel of physicians registered in Medscape. Physicians who
130 completed the test received a \$30.00 Amazon gift card. The test was budgeted for 518 physicians
131 completing the test. Seven hundred and eighty-eight practicing primary care physicians were
132 randomly selected and solicited via email, which resulted in a 66% response rate. The test
133 instrument was web-based and consisted of 24 multiple-choice questions. The objective
134 questions were taken from widely available safety and quality textbooks and clinical literature
135 and they were designed to reflect the practical safety and quality knowledge of practicing
136 physicians. There were six areas of questions: patient management, radiation risk, general safety
137 and quality, structure, process and outcome; and quality and safety definitions.

138 In terms of patient management, three common patient management vignettes addressed
139 the physician's clinical quality knowledge. For the breast cancer vignette, there were five
140 possible answers.¹⁰ For the renal mass, the American College of Radiology (ACR)
141 Appropriateness Criteria¹¹ gave the computed tomography (CT) abdomen without and with
142 intravenous (IV) contrast the highest appropriateness rating, 9, but this modality also had the
143 highest radiation level. The ultrasound kidney retroperitoneal with duplex Doppler had the next
144 highest rating, 8. The ACR states that appropriateness ratings of 9, 8, and 7 are "Usually

Physician safety & quality knowledge

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3 145 appropriate.” There were eight possible answers to the renal mass question.¹² Finally, in terms of
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5 146 patient management, the lung cancer screening consisted of five possible answers.¹³
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8 147 In terms of common radiation risks, five questions addressed physicians’ knowledge of
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10 148 common radiation risks.¹⁴⁻¹⁸ There were four choices per question, each choice differed by one
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12 149 base-ten log. In other words, the four possible answers to the question spanned a four-log range.
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15 150 In terms of common healthcare system safety and quality issues, there were seven
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17 151 questions.¹⁹⁻²⁵ There were five choices per question. In terms of Donabedian’s²⁶ model for
18
19 152 assessing safety and quality in terms of structure, process, and outcomes, there were seven
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21 153 questions. There were three choices per question. Two questions asked physicians to identify
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23 154 common quality²⁷ and safety²⁸ definitions from the IOM. There were five choices per question.
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25 155 The most difficult of the 24 questions was the IOM’s definition of safety. Limiting the definition
26
27 156 to “freedom from accidental injury,” would not have distinguished it from other safety
28
29 157 definitions. Therefore, the correct answer included the rest of the IOM definition, “where
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31 158 accidental injury can be due to error, as either the failure of a planned action to be completed as
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33 159 intended or the use of the wrong plan to achieve an aim.”
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38 160 The questions and answers are shown in Table 1. The questions were presented in a
39
40 161 random order and no changes were made to the questions during testing. The only instruction the
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42 162 physicians received was that they had to answer all the questions. The deidentified results were
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44 163 sent to the investigators by Medscape. The questions were not weighted. For each question, the
45
46 164 percent correct is calculated and, for each topic, the average percent correct was calculated. The
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48 165 Chi-square test was used to assess demographic differences and whether the categorial answer
49
50 166 frequencies differed from chance, and the Student’s t-test was used to compare continuous
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53 167 variables. The tests were performed using R (www.R-project.org) and significance was set at a
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168 probability of less than 0.05. The Uniformed Services University Institutional Review Board
169 approved this research.

170 Patient and Public Involvement

171 There was no patient and public involvement.

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173 Results

174 The study demographics of the 518 physicians are shown in Table 2. The medical
175 specialty of the participants was 46% General Internal Medicine and 54% Family Medicine. The
176 gender of the participants was 64% male and 35% female. There were no significant differences
177 between the participants and practicing physicians in terms of specialty, gender, and age.^{29,30}
178 There were no significant differences in the test scores within specialty, gender, and age, except
179 for slightly lower scores for physicians over 60 years of age compared to those under 60 years of
180 age, 0.45 (SD, 0.12) and 0.48 (SD, 0.11) respectively, $p = 0.003$. The median time to take the test
181 was 10.1 minutes.

182 The results are shown in Table 1. The average number of correct answers was 11.4 (SD,
183 2.69), 48% correct. Every physician answered at least four questions correctly and no physician
184 answered more than 20 questions correctly (Figure 1). For each question, the distribution of
185 answers was significantly different from that expected by chance ($p < 0.01$). The mean percent
186 correct for each of the five topics is shown in Figure 2.

187 In terms of the three common management vignettes, the average number of correct
188 answers was 1.3 (SD, 0.90), 45% correct. For the breast cancer vignette, fifty-five percent of the
189 physicians knew how to manage a woman with breast cancer who tested positive for a
190 deleterious BRCA mutation. For the renal mass vignette, 46%, knew the work up for an

Physician safety & quality knowledge

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3 191 indeterminate renal mass. For the lung cancer screening, 33%, knew the current approach to
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5 192 screening for lung cancer. Forty-six percent of the physicians correctly balanced the radiation
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8 193 risk against the marginal additional benefit of CT and chose the ultrasound test. These results are
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10 194 also consistent with a recent study that found that physicians rarely have accurate expectations of
11
12 195 the harms and benefits of clinical interventions, which the investigators attributed to a lack of
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14 196 knowledge.³¹

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17 197 In terms of common radiation risks, the average number of correct answers was 2.0 (SD,
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19 198 1.14), 40% correct. Sixty-one percent of the physicians correctly identified the radiation
20
21 199 exposure delivered by a chest x-ray, 60% correctly identified the radiation exposure delivered by
22
23 200 a mammogram, but only 45%, could correctly identify the radiation exposure delivered by a CT
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25 201 scan of the abdomen and pelvis. Furthermore, in terms of population risk, only 25% of the
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27 202 physicians correctly chose the annual natural radiation exposure of an individual and only 11%
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29 203 knew the degree to which a 20 mSv of radiation exposure increased the population risk of a fatal
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31 204 cancer. These results are consistent with a systematic review of computed tomography and other
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33 205 radiographic procedures that found a similarly low level of radiology exposure knowledge
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35 206 among physicians.³²

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38 207 In terms of commons healthcare system safety and quality issues, the average number of
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40 208 correct answers was 3.0 (SD, 1.27), 43% correct. Eighty-eight percent of the physicians knew the
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42 209 main hospital accrediting body, 74% knew the definition of beneficence, and 53% knew the
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44 210 Swiss Cheese model of accidents. But their accuracy was lower for questions regarding quality
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46 211 improvement tools, medication errors, 6-sigma, and harm detection – which were answered
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48 212 correctly by 34%, 19%, 19%, and 14% of the physicians, respectively. These results are
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50 213 consistent with a recent study of generalist and subspecialist Internal Medicine physicians which
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Physician safety & quality knowledge

214 found that they correctly answered 43% of the questions regarding the U.S. Food and Drug
215 Administration approval process.³³ They are also consistent with a study of physician
216 knowledge of central line-associated blood stream infection quality metrics that found that they
217 answered 61% of the questions correctly.³⁴

218 In terms of Donabedian's model, the average number of correct answers was 4.7 (SD,
219 1.50), 67% correct. This set of questions contained the easiest question, namely, whether "The
220 percentage of patients who are satisfied with their care" was a structure, process, or outcome
221 measure. Ninety-six percent of the physicians correctly answered that it was an outcome. The
222 physicians were highly accurate on classifying nosocomial infections, 89%, and staffing, 84%,
223 but they were only 53% correct in classifying beta-blockers, 53% correct in classifying
224 credentials, 50% correct in classifying the diabetic foot exam, and 45% correct in classifying
225 discharge instructions.

226 In terms of common safety and quality definitions, the average number of correct answers
227 was 0.39 (SD, 0.54), 20% correct. The definitions were published 19 years ago in *To Err Is*
228 *Human*. Despite the high visibility of *To Err Is Human*, only 33% of the physicians correctly
229 identified the IOM definition of quality. Only six percent of physicians knew the correct
230 definition of safety.

231 Discussion

234 U.S. physicians answered forty-eight percent of the safety and quality questions correctly.
235 They performed best on questions that required little safety and quality knowledge and worst on
236 question that required basic safety and quality knowledge. Our population was similar to the U.S.
237 physician population in terms of specialty, gender, and age. There were no significant differences

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238 within specialty, gender, or age; although the scores of physicians over 60 years of age were
239 slightly lower. These results are consistent with studies of physician knowledge of clinical harms
240 and benefits,³¹ radiology knowledge,³² knowledge of the FDA approval process,³³ and of
241 quality metrics.³⁴

242 We take the assessment of safety and quality knowledge to mean the results of an
243 objective test of either recall or recognition of facts related to safety and quality. Several studies
244 have assessed physicians' agreement with several safety statements³⁵ and with their judgment
245 regarding the effectiveness of certain interventions in reducing medical errors.³⁶ Finally, a multi-
246 disciplinary study in Western Lithuania of physicians, nurses, and nurse assistants found a low
247 level of safety knowledge.³⁷

248 Physicians want to practice safe, high quality medicine,³⁸ but they may not be aware of
249 how much they need to know about safety and quality. Furthermore, physicians need time to
250 learn about safety and quality, and they need the time and expertise required to use the
251 information in their EHRs to monitor the safety and quality of their practice. Although many
252 health care systems consider themselves to be healthcare learning systems,^{36,37} that belief does
253 not always translate into their assisting frontline clinicians in improving their safety and quality
254 knowledge.^{38,39}

255 The main limitation of this study is that there is no canonical safety and quality corpus.
256 Another limitation is that we may have overestimated physician knowledge because it used
257 multiple-choice questions that probe recognition. Physician scores might have been substantially
258 lower had they been asked to recall the correct answer to each question.

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261 Conclusions

262 Only forty-eight percent of the physicians' answers to the safety and quality questions
263 were correct. A national system has been put in place at the resident level to improve physician
264 safety and quality knowledge. Since knowledge is a prerequisite for performance, we expect that
265 future physicians' increased knowledge will result in less patient harm and improved clinical
266 outcomes. Future studies should objectively measure and track changes in physicians' objective
267 knowledge of safety and quality. We believe this to be the first prospective test of the safety and
268 quality knowledge of practicing U.S. primary care physicians.

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Physician safety & quality knowledge

270 Author contributions

271
272 HB: originated the study idea and designed the research project, analyzed the study data and
273 drafted the manuscript. HK: made important contributions to designing the research project and
274 analyzing the study data, and made significant contributions to the writing of the manuscript.

276 Conflicting and/or competing interests

277
278 The authors declare that they have no conflicts or competing interests.

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285 Ethics Approval

286
287 This study was approved by the Uniformed Services University of the Health Sciences
288 Institutional Review Board.

290 Patient and public involvement

291
292 There was no patient or public involvement in this study.

294 Data sharing

295
296 The frequency counts for each question are the data and they are provided in Table 2.

298 Disclaimer

299
300 The findings and conclusions of this paper are those of the authors and do not necessarily
301 represent the positions or views of the U.S. Department of Defense, the Military Health System,
302 the Defense Health Agency, or the Uniformed Services University of the Health Sciences.

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305
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Figure legends

Figure 1. Percentage of subjects answering the questions correctly

Figure 2. An integrated view of the mean percent correct for each of the five topic domains

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3 **444 Table 1. Questions and mean percent correct**

4 445

5 446 The correct answers are in bold. The grand mean percent correct is 48%.

6 447

7 448 **PATIENT MANAGEMENT: Mean percent correct = 45%**

8 449

9 450 A 42-year-old female presents to your clinic for the first time. She is s/p a left lumpectomy for
10 451 unilateral breast cancer. You order a BRCA test, which comes back positive for a deleterious
11 452 mutation.* You recommend:

Left breast mastectomy	48 (9%)
Bilateral mastectomy	166 (32%)
Bilateral salpingo-oophorectomy	8 (2%)
Left breast mastectomy and bilateral salpingo-oophorectomy	13 (3%)
Bilateral mastectomy and bilateral salpingo-oophorectomy	283 (55%)

12 453

13 454 A 22-year-old female transferred to your clinic from another facility. She sees you for the first
14 455 time today. She states that she has a 2 cm indeterminate renal mass that was incidentally detected
15 456 during a work-up for a suspected kidney stone almost 3 years ago. Her previous physician told
16 457 her that it needed to be re-imaged within 3 years. She does not remember what imaging test was
17 458 used to detect the mass. She denies any new symptoms or blood in her urine. She is here for an
18 459 imaging test.* Pick the best test.

Arteriography kidney	1 (0%)
CT abdomen with and without contrast	114 (22%)
MRI abdomen without contrast	13 (3%)
X-ray intravenous urography	4 (1%)
CT abdomen without contrast	42 (8%)
MRI abdomen with and without contrast	32 (6%)
U/S kidney retroperitoneal with Doppler	239 (46%)
CT abdomen with contrast	73 (14%)

19 460

20 461 A retired 66-year-old man presents to your clinic for a routine physical examination. He has a
21 462 history of COPD. You ask about his tobacco history and he tells you that he started smoking
22 463 when he was 25 years old, he smoked 1 pack-per-day for 25 years, and he stopped smoking
23 464 when he was 50 years old. He wants to know if he should do something to assess his risk of lung
24 465 cancer.* You order:

No imaging	173 (33%)
Chest x-ray, PA and lateral	72 (14%)
CT of the chest without contrast	35 (7%)
CT of the chest with and without contrast	16 (3%)
A low-dose CT of the chest	222 (43%)

25 466

26 467 * These are hypothetical patients that were included as test questions.

468 **RADIATION RISK: Mean percent correct = 40%**

469

470 The effective dose of a two-view chest radiograph is approximately:

0.01 mSv (millisievert)	62 (12%)
0.1 mSv	316 (61%)
1.0 mSv	112 (22%)
10.0 mSv	28 (5%)

471

472 The effective dose of a two-view mammogram is approximately:

0.04 mSv (millisievert)	116 (22%)
0.4 mSv	313 (60%)
4.0 mSv	84 (16%)
40.0 mSv	5 (1%)

473

474 The effective dose of a single CT of the abdomen and pelvis, with and without contrast is
475 approximately:

0.02 mSv (millisievert)	9 (2%)
0.2 mSv	69 (13%)
2.0 mSv	206 (40%)
20.0 mSv	234 (45%)

476

477 For the average American living at sea level, the annual effective dose of radiation is
478 approximately:

0.03 mSv (millisievert)	223 (43%)
0.3 mSv	148 (29%)
3.0 mSv	127 (25%)
30.0 mSv	20 (4%)

479

480 Receiving at least 20 mSv (millisieverts) of radiation increases an adult person's risk of a fatal
481 cancer by approximately:

1 in 100,000 – 1,000,000	116 (22%)
1 in 10,000 – 100,000	183 (35%)
1 in 1,000 – 10,000	164 (32%)
1 in 100 – 1,000	55 (11%)

482

483 **GENERAL SAFETY AND QUALITY: Mean percent correct 45%**

484

485 The main hospital accreditation body in the United States is:

Institute for Healthcare Improvement (IHI)	2 (0%)
American Hospital Association (AHA)	16 (3%)

Physician safety & quality knowledge

National Committee for Quality Assurance (NCQA)	27 (5%)
The Joint Commission (JC)	456 (88%)
Centers for Medicare and Medicaid Services (CMS)	17 (3%)

486

487

Which one of the following refers to acting in the best interest of the patient?

Respect for autonomy	60 (12%)
Beneficence	382 (74%)
Nonmaleficence	62 (12%)
Justice	5 (1%)
Fairness	9 (2%)

488

489

Which of the following is the correct description of the Swiss cheese model of accidents?

Many people making the same mistake over and over again will eventually cause an accident.	65 (13%)
It usually takes several things going wrong for an accident to happen.	274 (53%)
If a person makes the same mistake many times, it will eventually cause an accident.	57 (11%)
It is about filling in holes in the system.	108 (21%)
A person who makes a root cause error will cause an accident.	14 (3%)

490

491

Select from the list below the method that is NOT a tool for analyzing quality improvement.

Process mapping	20 (4%)
Flow charts	58 (11%)
Fishbone diagrams	127 (25%)
Discharge checklists	177 (34%)
Pareto charts	136 (26%)

492

493

Which of the following is NOT a part of "6-sigma"?

Its goal is to reduce errors to a rate of 3.4 errors per million opportunities to make an error.	66 (13%)
It involves a series of five steps: define, measure, analyze, improve, and control.	93 (18%)
It is especially useful for processes that do not happen frequently.	99 (19%)
Its practitioners are known as black belts.	165 (32%)
It is six standard deviations from the average.	95 (18%)

494

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497 The most frequent reason for hospital medication errors is:

Prescribing	98 (19%)
Transcribing	244 (47%)
Dispensing	64 (12%)
Administration	93 (18%)
Monitoring	19 (4%)

498
499 Several methods for detecting harms are shown below. Used in their usual way, which
500 method detects the most harms?

Direct observation of care	129 (25%)
Reports by clinicians	30 (6%)
IHI global trigger tools	73 (14%)
AHRQ Patient Safety Indicators	169 (33%)
Chart reviews	117 (23%)

501
502 **STRUCTURE, PROCESS, OUTCOME: Mean percent correct = 67%**

503
504 Identify whether this is an example of a structure (S), process (P), or outcome (O).

505 Q. The percentage of patients who are satisfied with their care.

S	6 (1%)
P	17 (3%)
O	495 (96%)

506
507 Identify whether this is an example of a structure (S), process (P), or outcome (O).

508 Q. Percentage of patients that experience a nosocomial infection.

S	18 (3%)
P	37 (7%)
O	463 (89%)

509
510 Identify whether this is an example of a structure (S), process (P), or outcome (O).

511 Q. There is enough clinical staff to care for the patients.

S	436 (84%)
P	46 (9%)
O	36 (7%)

512
513 Identify whether this is an example of a structure (S), process (P), or outcome (O).

514 Q. The percentage of patients with an acute myocardial infarction who receive a beta-blocker.

S	26 (5%)
P	274 (53%)

O	218 (42%)
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515

516 Identify whether this is an example of a structure (S), process (P), or outcome (O).

517 Q. Clinicians are properly credentialed.

S	272 (53%)
P	226 (44%)
O	20 (4%)

518

519

520 Identify whether it is an example of a structure (S), process (P), or outcome (O).

521 Q. The percentage of diabetic patients that have an order for an annual foot exam.

S	55 (11%)
P	257 (50%)
O	206 (40%)

522

523 Identify whether this is an example of a structure (S), process (P), or outcome (O).

524 Q. The percentage of patients that are given discharge instructions.

S	12 (2%)
P	234 (45%)
O	272 (53%)

525

526

527 **QUALITY AND SAFETY DEFINITIONS: Mean percent correct = 48%**

528

529 The Institute of Medicine's definition of quality is:

Providing acceptable and expected medical care, where acceptable means medical care that patients understand, agree to, and can afford, and expected means performance at the current professional standard of care.	183 (35%)
Doing the right thing at the right time for the right individual to get the best possible results.	75 (14%)
The degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge.	170 (33%)
A system in which organizations are accountable for continuously improving the quality of their services and safeguarding high standards of care.	65 (13%)
Receiving the best care possible for one's illness or condition.	25 (5%)

530

531 The Institute of Medicine's definition of safety is:

The minimization of the risk of any harm, and the amelioration of the effect of a harm, to a person caused by medical care.	135 (26%)
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Freedom from accidental or preventable injuries produced by medical care.	60 (12%)
Assuring that all care is safe for all patients requires examining the systems and processes of care, identifying the points of failure, and modifying the factors that cause systems to break down.	90 (17%)
The avoidance, prevention, and amelioration of adverse outcomes or injuries stemming from the process of care.	200 (39%)
Freedom from accidental injury, where accidental injury can be due to error, as either the failure of a planned action to be completed as intended or the use of the wrong plan to achieve an aim.	33 (6%)

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536 **Table 2. Physician characteristics^a**

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	Study population Number and Percent	National population Percent
Medical Specialty^b		
Family Medicine	280 (54%)	53%
Internal Medicine	238 (46%)	47%
Gender^c		
Male	331 (64%)	66%
Female	187 (36%)	34%
Age^c		
< 39	131 (25%)	21%
40 – 49	160 (31%)	24%
50 – 59	124 (24%)	24%
60 – 69	85 (17%)	20%
70 +	18 (3%)	11%

^aThere were no significant differences between the study population and the national population in terms of medical specialty, gender, or age.

^bNational: <https://www.ahrq.gov/research/findings/factsheets/primary/pcwork1/index.html>

^cNational: Young A, Chaudhry HJ, Pei X, Halbesleben K, Polk DH, Dugan M. A census of actively licensed physicians in the United States, 2014. J Med Reg 2015;101(2):8-23

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Figure 1. Percentage of subjects answering the questions correctly

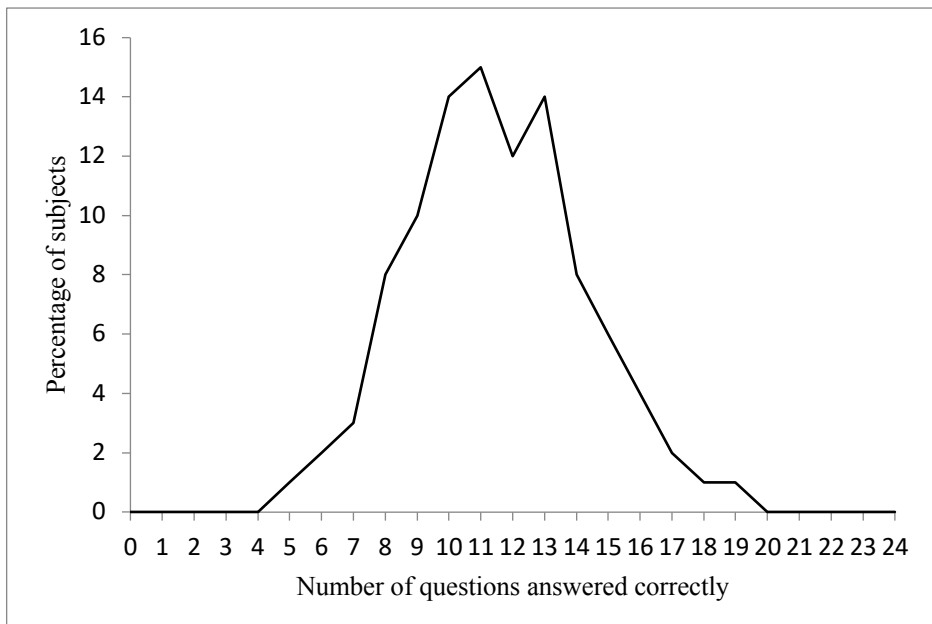
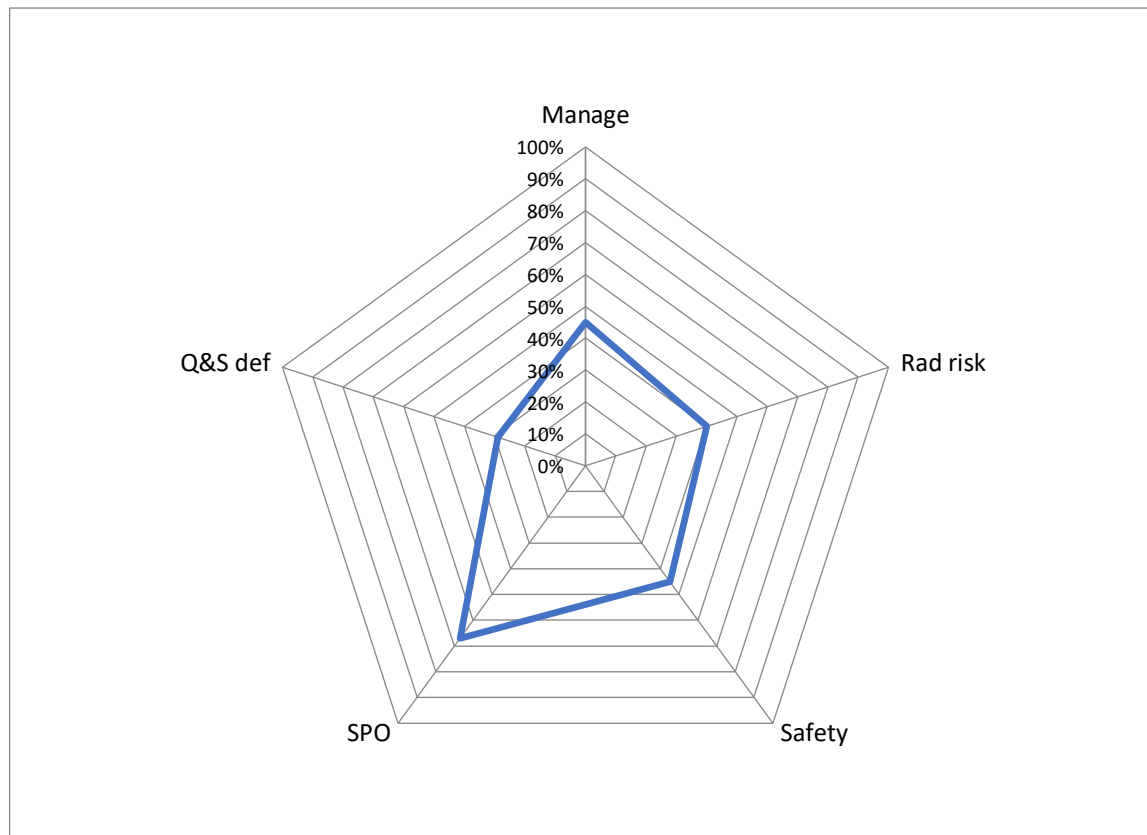


Figure 2. An integrated view of the mean percent correct for each of the five topic domains



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60STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract
P1L1		(b) Provide in the abstract an informative and balanced summary of what was done
P2		and what was found
Introduction		
Background/rationale P3-4, L112-123	2	Explain the scientific background and rationale for the investigation being reported
Objectives P3-4, L124-170	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design P4L174-175	4	Present key elements of study design early in the paper
Setting P4L1-175-176	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants P4L174-184	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants
Variables P4-5L185-213	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement P5L214	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias P5L2214-217	9	Describe any efforts to address potential sources of bias
Study size P4L177-179	10	Explain how the study size was arrived at
Quantitative variables P5L217-218	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods P5L219-232	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses
Results		
Participants P6L236	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram
Descriptive data P6L236-243	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest
Outcome data P6-8	15*	Report numbers of outcome events or summary measures
Main results P6-8	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

		adjusted for and why they were included
		(b) Report category boundaries when continuous variables were categorized
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses NA	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results P8L330-335	18	Summarise key results with reference to study objectives
Limitations P9L372375	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation P9-10L378-407	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability P10L410-411	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding P11L426-429	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.