# Radiation Exposure and Cost Influence Physician Medical Image Decision Making

## *A Randomized Controlled Trial*

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**Background:** It is estimated that 20%–40% of advanced medical imaging in the United States is unnecessary, resulting in patient overexposure to radiation and increasing the cost of care. Previous imaging utilization studies have focused on clinical appropriateness. An important contributor to excessive use of advanced imaging may be a physician "knowledge gap" regarding the safety and cost of the tests.

**Objectives:** To determine whether safety and cost information will change physician medical image decision making.

**Research Design:** Double-blinded, randomized controlled trial. Following standardized case presentation, physicians made an initial imaging choice. This was followed by the presentation of guidelines, radiation exposure and health risk, and cost information.

**Results:** Approximately half (57 of 112, 50.9%) of participants initially selected computed tomography (CT). When presented with guideline recommendations, participants did not modify their initial imaging choice ($P = 0.197$). A significant reduction (56.3%, $P < 0.001$) in CT ordering occurred after presentation of radiation exposure/health risk information; ordering changed to magnetic resonance imaging or ultrasound (US). A significant reduction (48.3%, $P < 0.001$) in CT and magnetic resonance imaging ordering occurred after presentation of Medicare reimbursement information; ordering changed to US. The majority of physicians (31 of 40, 77.5%) selecting US never modified their ordering. No significant relationship between physician demographics and decision making was observed.

**Conclusions:** This study suggests that physician decision making can be influenced by safety and cost information and the order in which information is provided to physicians can affect their decisions.

**Key Words:** patient safety, medical imaging, cost, radiation exposure, physicians, clinical decision support, decision making

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The annual per capita radiation dose that the US population is exposed to has doubled over the past 3 decades,[1–3] whereas the frequency of diagnostic radiologic examinations have increased almost 10-fold.[3] A major contributor to population radiation exposure is computed tomography (CT). The frequency of CT scanning alone has increased from 3 million scans (1980) to approximately 80 million (2010).[3] The risks associated with radiation doses typical of a CT scan are a possible public health issue.[2,4–7]

Evidence suggests that 20%–40% of all CT scans are unnecessary.[8–14] Contributors to excessive use of CT imaging include patient expectations,[7,9,11,12,14–16] the practice of "defensive" medicine,[12,14–16] and lack of physician knowledge.[7,9,12,14–17] Patients' physicians are responsible for weighing the risks and benefits of medical tests.[4,18]

One approach to closing physician "knowledge gaps" in clinical practice is the use of clinical decision support systems (CDSSs) to assist in decision making.[19–21] Evidence suggests that CDSS can impact on physician ordering behavior.[8,10–12,16,21–25] Some CDSS include cost awareness information.[26–30] CDSS embedded in computerized physi-

cian order entry systems have effectively influenced medical image ordering.[8–10,12,22,24,31] Effective CDSS are unambiguous, actionable, fast, and evidence based.[19,32]

In this study, we examine the effect on physician decision making of presenting radiation and cost information in the context of medical image ordering. We hypothesize that: when physicians are presented with a number of equally medically appropriate imaging tests with corresponding radiation exposure and health risk information, they will avoid ordering imaging studies with highest radiation exposure; likewise, when presented with a number of equally medically appropriate imaging tests with corresponding cost information, physicians will avoid ordering imaging studies with the highest costs.

## METHODS

This institutional review board–approved study was a randomized double-blinded controlled trial conducted between June and August 2012 at the University of Nebraska Medical Center and Saint Louis University's Belleville Family Medicine program; both in partnership with the US Air Force. Eligible participants included all affiliated family medicine staff and resident physicians.

Following informed consent, participants were randomly allocated to groups through a sealed envelope process and on-line registration. Participants were allocated to either radiation then cost information (RADS-COST) or cost then radiation information (COST-RADS). The participant study flow is shown in Figure 1.

The intervention consisted of a clinical vignette with follow-up decision screens (Supplemental Digital Content 1, http://links.lww.com/MLR/A466). The vignette described a 22-year-old female patient presenting with an indeterminate renal mass incidentally previously detected. Following case presentation, the physicians were prompted to select an imaging test for this patient; 9 test options were randomly presented.

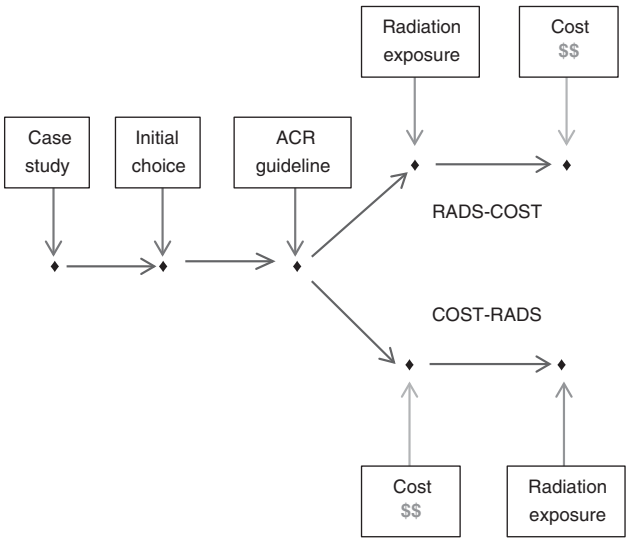


**FIGURE 1.** Participant study flow. ACR indicates American College of Radiology; COST-RADS, cost then radiation information; RADS-COST, radiation then cost information.

After the initial imaging decision, participants were presented with the American College of Radiology (ACR) Appropriateness Criteria rankings for this clinical scenario. A legend to cross-reference each option's ACR score with clinical appropriateness was included. Images with a rating of 7–9 were "usually appropriate" which included magnetic resonance imaging (MRI) (with and without contrast), CT (with and without contrast), and ultrasound (US); images with rating of 4–6 were "may be appropriate" with no modalities falling into this category; images with rating of 1–3 were "not usually appropriate" which included the remaining 6 imaging options: arteriography kidney, CT abdomen (with and without contrast), Tc-99m dimercapto succinic acid scan kidney, MRI abdomen (without contrast), x-ray intravenous urography, MRI abdomen (with and without contrast), US kidney retroperitoneal with Doppler, CT abdomen (with contrast), and CT abdomen (without contrast). The participants were provided the opportunity to modify their original imaging decision.

The sequence of the next 2 decision screens varied on the basis of group assignment. The participants in the RADS-COST group were given radiation exposure information for the CT abdomen (without and with contrast), MRI abdomen (without and with contrast), and US and asked to choose an imaging modality. After that decision they were given cost information and asked to choose an imaging modality. The participants in the COST-RADS group were given cost information for the same 3 imaging tests and asked to choose an imaging modality. After that decision, they were given radiation information for the 3 imaging options and asked to choose an imaging modality. Both the groups received the same radiation and cost information.

The exposure information was derived from the ACR Appropriateness Criteria. The estimated radiation exposure was listed as 10–30 mSv for CT of the abdomen (without and with contrast) and 0 radiation exposure for the MRI and US. Health risk information was based on population-based epidemiological studies.[1–3,18,33,34]

The cost information for the 3 imaging tests was based on the Centers for Medicare and Medicaid national averages. The cost presented was $1478 for MRI (without and with contrast), $916 for CT (without and with contrast), and $272 for US. Once presented with cost information, the physicians were provided the option of modifying their medical imaging decision.

The primary outcome measure was the physicians' selection of the imaging tests after receiving ACR Appropriateness Criteria information, radiation information, and cost information.

Power for within-subject comparisons is based on the Stuart-Maxwell test with a 5%, 2-sided significance level and within-subject correlation of 0.5. A sample size of 50 will have 94% power to detect a difference in the proportion selecting other than "usually appropriate" studies if 30% choose such a study in the absence of evidence and 10% choose such a study when evidence is presented. Power for comparisons between the RADS-COST group and COST-RADS group, or

between physicians and residents was assessed using Fisher exact test with a 5%, 2-sided significance level. If the sample size per group is 50 and the difference in proportions between groups is at least 30, power will exceed 80%.

Data were recorded into SPSS, v. 20 (IBM Corp, NY) for analysis and were summarized as frequencies and percent. Changes in ordering decisions after presentation of evidence were analyzed in STATA, v. 12 (StataCorp, TX) using the Stuart-Maxwell test of marginal homogeneity. Subanalyses using Fisher exact test were performed comparing ordering decisions in the initial selection and the decision screen selections to assess potential statistical effect of participant demographics.

## RESULTS

The study consisted of 112 family practice physicians divided into 2 groups; the RADS-COST group (n = 65) and the COST-RADS group (n = 47). Gender distribution was balanced as was percentage of uniformed physicians. Half of the participants were under 30 years of age. There were no significant differences between the 2 groups in terms of demographics (Table 1) or image ordering decisions.

The initial physician image ordering is shown in Table 2. Fifty-seven of the 112 participants (50.9%) ordered a CT, 40 participants (35.7%) ordered US, 9 (8.0%) ordered an MRI, and 6 (5.4%) ordered other tests. After presentation of the ACR Appropriateness Criteria, the medical imaging orders were 61 (54.5%) CT abdomen, 42 (37.5%) US, 7 (6.3%) MRI, and 2 (1.8%) other tests. There was an increase in CT and US ordering and a corresponding decrease in MRI ordering. The change from the initial test selection and the section after presentation of the evidence-based ACR Appropriateness Criteria was not significant ($P = 0.197$).

Following Appropriateness Criteria-related selections, physicians were presented with either RADS (RADS-COST group) or COST (COST-RADS group) information. In the RADS-COST group, after receiving radiation information, CTs dropped to 14 (21.5%), MRIs increased to 15 (23.1%), and US increased to 36 (55.4%). These findings represented a statistically significant ($P < 0.001$) shift away from the CT in favor of either MRI or US. The RADS-COST group was then presented with COST information. The number of CTs remained constant at 14 (21.5%), MRIs dropped to 6 (9.2%), and US increased to 45 (69.3%). Although there were no change in CT orders, MRI orders fell significantly ($P < 0.01$) in favor of US.

Following the Appropriateness Criteria-related selections, the physicians in the COST-RADS group were presented with COST information. After information presentation, CTs dropped to 15 (31.9%), MRIs to 0, and US increased to 32 (68.1%). These findings represented a statistically significant ($P < 0.001$) shift away from the CT and MRI to US. Substantially, more physicians decided to change from a higher cost to lower cost imaging. The COST-RADS group was then presented with RADS information. After receiving this information, CTs slightly increased to 16 (34.0%), MRIs remained at 0, and US slightly decreased to 31 (66.0%). There was no statistical difference ($P = 0.317$) in ordering when RADS was presented after cost.

Once all 3 types of information were provided (Appropriateness Criteria, radiation exposure, and cost), participants in both groups were equally likely to order US [45 of 65 in the RADS-COST group (69.2%) vs. 31 of 47 in the COST-RADS group (66.0%), $P = 0.838$]. Among the 36 participants who did not order US, those who received radiation information before cost were more likely to order MRI (6/20, 30%) than those who received cost before radiation information (0/16, 0%, $P = 0.024$), which suggests that that information presented earlier had a greater influence over ordering behavior than that presented subsequently.

In comparing the ordering of CT, MRI, and US (Table 3), the US was the most consistent for both groups (78.3% in RADS-COST group, 76.5% in COST-RADS group).

## DISCUSSION

This study suggests that physician decision making can be influenced by safety and cost information and the order in which information is provided can affect their decisions.

**TABLE 1.** Participant Demographics

| | RADS-COST Group (n = 65) | COST-RADS Group (n = 47) | Both Groups (n = 112) |
|---|---|---|---|
| Staff physician | 24 (36.9%) | 16 (34.0%) | 40 (35.7%) |
| Resident | 41 (63.1%) | 31 (66.0%) | 72 (64.3%) |
| Civilian | 29 (44.6%) | 24 (51.1%) | 53 (47.3%) |
| Uniformed | 36 (55.4%) | 23 (48.9%) | 59 (52.7%) |
| Female | 27 (41.5%) | 23 (48.9%) | 50 (44.6%) |
| Male | 38 (58.5%) | 24 (51.1%) | 59 (55.4%) |
| Age (y) | | | |
| <30 | 26 (40.0%) | 25 (53.2%) | 51 (45.5%) |
| 31–40 | 22 (33.8%) | 15 (31.9%) | 37 (33.0%) |
| 41–50 | 10 (15.4%) | 2 (4.3%) | 12 (10.7%) |
| 51+ | 7 (10.8%) | 5 (10.6%) | 12 (10.7%) |

Statistical comparison of groups using Fisher exact test—NS.
COST-RADS indicates cost then radiation information; RADS-COST, radiation then cost information.

**TABLE 2.** Physician Medical Image Order Choices

| | Initial Choice | Guideline | Radiation | Cost |
|---|---|---|---|---|
| RADS-COST (n = 65) | | | | |
| CT without and with contrast | 31 (47.7%) | 32 (49.2%) | 14 (21.5%) | 14 (21.5%) |
| MRI without and with contrast | 6 (9.2%) | 6 (9.2%) | 15 (23.1%) | 6 (9.2%) |
| Ultrasound | 23 (35.4%) | 25 (38.5%) | 36 (55.4%) | 45 (69.3%) |
| Other | 5 (7.7%) | 2 (3.1%) | | |
| | | Initial vs. guideline $P = 0.371$ | Guideline vs. radiation $P < 0.001$ | Radiation vs. cost $P < 0.01$ |
| COST-RADS (n = 47) | | | | |
| CT without and with contrast | 26 (55.3%) | 29 (61.7%) | 15 (31.9%) | 16 (34.0%) |
| MRI without and with contrast | 3 (6.4%) | 1 (2.1%) | 0 | 0 |
| Ultrasound | 17 (36.2%) | 17 (36.2%) | 32 (68.1%) | 31 (66.0%) |
| Other | 1 (2.1%) | 0 | | |
| | | Initial vs. guideline $P = 0.372$ | Guideline vs. cost $P < 0.001$ | Cost vs. radiation $P = 0.317$ |

COST-RADS indicates cost then radiation information; CT, computed tomography; MRI, magnetic resonance imaging; RADS-COST, radiation then cost information.

Radiation exposure information is important. Evidence suggests that many practicing physicians do not understand the radiation exposure and health risks associated with the advanced medical imaging they order for their patients.[35–39] Also, there is a compelling body of evidence on the association of low-dose ionizing radiation exposure from medical imaging and heightened cancer risk.[2,6,18,40–42]

Cost information is important because there is a wide variation in the cost of medical imaging options available to clinicians and imaging is among the fastest growing Medicare expenses.[7,12,14,43]

The order in which the physicians were presented with information regarding estimated radiation exposure and cost influenced clinical decision making. Participants given radiation information changed their preferred imaging test from CT to MRI and US. When subsequently given cost information these physicians did not further reduce CT ordering, but did modify their MRI testing in favor of US. Participants given cost information also significantly reduced their CT scan ordering in favor of US; many of these participants did not further modify their imaging preferences when given radiation exposure information.

Some (22 of 112; 19.6%) of the physicians chose CT tests and were impervious to safety and cost information. It could be that these physicians believed that CT was the only appropriate test for this patient or were not interested in changing their minds once they chose an imaging test.

Our study addresses several important issues. First, there are numerous medical imaging guidelines; some may not always differentiate among clinically appropriate images that have less radiation exposure or lower cost. Second, how clinicians are presented with radiation and cost information appears to matter.

This study indicates that physician knowledge about the cost of imaging tests influences their decision making. In an era of mounting health expenditures, further investigation of the role of cost may be warranted. Finally, this study supports a growing literature which demonstrates a substantial physician knowledge gap on issues related to medical image ordering.[7,9,12,14–17,35–37,39]

Our study has limitations. Our randomization process resulted in a less-than-balanced number of physicians (ie, 65 vs. 47) but there were no significant differences between the 2 double-blinded groups in terms of demographics or initial imaging selections. Significance is not adjusted for multiple comparisons because we tested only a limited number of preplanned hypotheses. However, if we applied Bonferroni correction, which is conservative, to the hypotheses tested in this study all but one of the significant findings would remain. The finding that MRI orders fell significantly ($P < 0.01$) in favor of US after presentation of cost information in the RADS-COST group would no longer be statistically significant; this finding should be interpreted with caution. Also, this study may not generalize to other clinical scenarios or other physician specialties.

In conclusion, in a clinical scenario with 3 equally appropriate radiographic tests, safety and cost information did affect physician decision making. This information should be considered for inclusion in medical imaging CDSS.

**TABLE 3.** Physicians Who did not Change Medical Image Order

| | RADS-COST Group (n = 65) | | | COST-RADS Group (n = 47) | | |
|---|---|---|---|---|---|---|
| Order | Initial Choice | Final Choice | No Change From Initial Order (%) | Initial Choice | Final Choice | No Change From Initial Order (%) |
| CT (without and with contrast) | 31 | 9 | 29.0 | 26 | 13 | 50.0 |
| MRI (without and with contrast) | 6 | 3 | 50.0 | 3 | 0 | 0 |
| Ultrasound | 23 | 18 | 78.3 | 17 | 13 | 76.5 |
| Other | 5 | 0 | 0 | 1 | 0 | 0 |

COST-RADS indicates cost then radiation information; CT, computed tomography; MRI, magnetic resonance imaging; RADS-COST, radiation then cost information.

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