Radiology

Falling Prey to the Sunk Cost Bias: A Potential Harm of Patient Radiation Dose Histories[1]

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In recent years, enthusiasm over the diagnostic capabilities of computed tomography (CT) has been tempered by increasing concerns about ionizing radiation and its adverse health effects (1–5). In 2009, widely publicized radiation overdoses that occurred during CT of the brain prompted both Congress and the U.S. Food and Drug Administration to investigate existing gaps in CT safety procedures (2,6). During this same period, researchers published studies attempting to project radiation-induced cancer risks associated with CT, with one study estimating that 29000 Americans would develop future cancers as a result of CT examinations performed in 2007 (1,4). Although these studies have been criticized as inflating cancer risks, they have nonetheless contributed to a substantial change in ordering practices: Many physicians now think twice before requesting a CT scan.

Evolution of Patient Dose Registries

For the most part, a very positive culture change has resulted. Many institutions are implementing new CT protocols and industry is developing new technologies to lower radiation doses. Furthermore, there is increasing use of decision support systems to curb overutilization, and national dose registries are under way that will allow facilities to compare their CT doses against national benchmarks (3,5,7,8). The latter will be increasingly facilitated by automated technologies designed to capture dose-related parameters, which are soon to be more widely available (9,10). In the near future, most institutions will be able to query a database that will provide aggregate dose information from all CT examinations performed at their institution (9,10).

Going one step further, some have advocated combining automated dose-capturing technologies with institutional electronic medical records to create patient-specific radiation dose histories (11). Such histories would allow physicians to easily track and access a patient's cumulative exposure to diagnostic radiation (11). Authorities have alluded to the need for such histories, with the Joint Commission recently lamenting that "any physician can order tests involving exposure to radiation at any frequency, with no knowledge of when the patient was last irradiated or how much radiation the patient received" (12). Although it is obvious that patient dose histories could provide valuable information that would help avoid duplicate—and therefore unnecessary—CT examinations, physicians must also be careful not to misuse imaging histories in clinical decision making.

The Pitfall: Two Different Patients with Possible Appendicitis

To illustrate the potential for misuse of a patient's dose history, consider the following clinical situation. Two patients, patient A and patient B, report to the emergency department. Both are 35-year-old men with abdominal pain, and their presentations evoke the possibility of appendicitis. However, the level of suspicion, identical for each, is considered low. Patient A is otherwise healthy, with no significant past medical history and no previous exposure to diagnostic radiation. An emergency department physician weighs the risks and benefits of CT for patient A and determines that CT is warranted. Patient B has a history of early-stage testicular cancer, diagnosed and treated at the age of 25 years, and is now considered cured. As a result, he has undergone 20 abdominopelvic CT examinations during the past decade for cancer surveillance, the last of which was 6 months

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ago; his cumulative radiation exposure is 180 mSv. Should patient B's radiation dose history be considered when deciding whether CT should be performed to rule out appendicitis?

According to the linear no-threshold model, the most widely accepted model linking radiation exposure to cancer risk, each incremental dose "unit" (effective dose) in a patient's history has an equal and independent effect on a patient's risk for developing a radiation-induced cancer (13). This means that the harms of the CT examination in question would be identical for patients A and B, despite their different radiation dose histories. Therefore, if patients A and B have identical benefits to be gained from scanning, and if these benefits are determined to exceed the risks of CT for patient A, the same must be true for patient B. Put another way, decisions to perform CT on patient B should not be influenced by his past exposure history. Durand (11) elegantly outlined the logic that underscores this decision-making process, illustrating linear no-threshold model implications from a mathematical standpoint. Nevertheless, although this knowledge is both available and deducible, its application can seem counterintuitive and is inconsistent with arguments in favor of using dose histories to guide decisions regarding the use of CT.

The Sunk Cost Bias and Its Potential to Influence Decision Making

Why does it seem natural to want to take patient B's radiation dose history into account? A well-known cognitive fallacy known as the sunk cost bias provides a plausible explanation and represents an important decision-making tendency to highlight—and educate against—as patient-level dose registries become commonplace. Sunk costs, commonly conceptualized in terms of money, represent irrecoverable losses. It is a well-known economic maxim that sunk costs should not influence the calculation of future benefits or losses (14–16). Nonetheless, behavioral economists and cognitive psychologists have shown that human beings tend to act irrationally, honoring sunk costs despite their irrelevance (14–16). Instead of recognizing that sunk costs are irrecoverable, human beings commonly make decisions that attempt to mitigate or address these irreversible past occurrences (14–16).

In 1985, Arkes and Blumer published a landmark article in *Organizational Behavior and Human Decision Processes* (14), where they investigated human propensities for succumbing to the sunk cost fallacy in experiments conducted on college students in Oregon and Ohio. In one experiment, students were presented with one of two scenarios (14). In the first, company A invests $10 million to develop a new airplane. After company A is 90% finished with their project, company B begins to sell a similar airplane that is cheaper and higher in quality than company A's projected product. When students were asked whether company A should spend the remaining $1 million to complete their product, most said yes, thereby succumbing to the sunk cost fallacy (14). In another experiment, company A has not invested any money in developing the new airplane but has $1 million of research funds to expend (14). An employee suggests that this be used toward building the new airplane, but it is known that company B is already selling a product, as above, that is superior and cheaper than one that could be made by company A. In this setting, which omitted sunk cost considerations, most students sensibly responded that they would not invest the $1 million toward the new airplane (14).

In our clinical example, a physician may hesitate to order the CT examination for patient B when made aware of patient B's past radiation exposures, weighing patient B's cumulative radiation-induced cancer risks (past and present) against the benefits of an additional CT examination. However, only the risk of the current CT examination should be considered in this risk-benefit analysis. A decision against an additional CT examination will not reduce the cancer risks—sunk costs—incurred with previous examinations. Thus, performing CT in patient A but not patient B is illogical. More broadly stated, for any given patient with a history of radiation exposures, if imaging decisions are made—or dose-reduction measures taken—that deviate from what an identical patient with no previous imaging history would receive, in an attempt to somehow mitigate effects of previous CT examinations, the logic behind these decisions is flawed and the decisions may lead to more harm than good. If it was the Joint Commission's intention to imply, in their above statement, that physicians should use patients' cumulative exposure histories to inform future imaging decisions, then their statement provides an example of the sunk cost bias. It is crucial that all responsible parties understand the human tendency to succumb to this bias.

In an effort to curb unnecessary radi ation related to imaging overutilization, some insurers and radiology benefits managers have already incorporated patient radiation dose histories into imaging ordering systems (17,18). In the case of one insurer, if a patient's cumulative dose history exceeds 50 mSv, the ordering physician receives a dose limit threshold notification informing them that the patient "potentially fall[s] into a higher risk category due to their personal exposure" and that "[d]iagnostic imaging exams that involve ionizing radiation…should only be ordered when the benefits significantly outweigh the risks" (17). Although well intentioned, such attempts to influence ordering practices on the basis of patient-level dose histories are misguided and encourage potentially harmful sunk cost biases.

Advantages of Patient Dose Registries

Patient-level dose registries will, however, provide important opportunities for quality improvement and research initiatives. These registries will allow authorities to query cumulative doses for

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designated types of patients—for example, patients with inflammatory bowel disease or testicular cancer, who may undergo numerous imaging examinations during their lifetimes. With use of this information, institutions will be able to formulate prospective dose-reduction strategies for targeted groups, allowing for a more patient-centered approach to dose optimization than is currently possible. Patient-level dose registries will also allow institutions to make detailed comparisons of their dose levels to national averages to determine if they are keeping up with contemporary dose-reduction practices and safety standards (8). Such registries will also facilitate longitudinal observational research that will more precisely elucidate the relationship between cancer risk and ionizing radiation levels associated with diagnostic imaging.

Although patient dose histories should not directly factor into prospective imaging decisions, in specific circumstances they can nonetheless benefit care at the individual patient level. For example, in populations for whom several CT examinations are anticipated and for whom, as a result, prospective dose-reduction strategies have been implemented at the institutional level, patient dose histories will enable physicians to track adherence for each of their patients. Consider a 25-year-old man with newly diagnosed early-stage testicular cancer. Suppose that in his hospital, according to accepted protocols, appropriately imaged patients with early-stage testicular cancer should typically be exposed to less than 120 mSv in the 10 years after diagnosis. Availability of a continually updated patient-level dose history will enable his care team to quickly identify and correct any unintended deviations made during ordering or scanning. In addition, patient dose histories will facilitate transparent discussions between physicians and patients about patients' cumulative exposures and radiation risks incurred. Although these risks cannot be mitigated, a physician's ability to responsibly convey medical risks remains central to constructive and meaningful physician-patient relationships.

Conclusion

Although patient dose histories will make valuable contributions to quality improvement and research initiatives, care must be taken to avoid misuse by physicians when making imaging decisions for individual patients. Health care professionals should be carefully educated about the appropriate use of patient dose histories before their widespread implementation and availability. Educational efforts should stem from the radiology community and focus on ensuring that radiologists and referring clinicians alike understand central concepts and implications of the linear no-threshold model; the sunk cost bias should be highlighted as an important potential pitfall in this context. Ultimately, educational initiatives must reach a broader audience, including insurers, manufacturers, and policymakers. If we fail to prioritize related educational efforts, we all risk succumbing to sunk cost biases and our well-intentioned decisions to spare patients additional diagnostic radiation may ultimately cause more harm than good.

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