Assessment of Nuclear Security Culture at Radiological Facilities Across United States.

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Abstract- The greatest challenge to guarding against radiological threats (such as, radiological dispersal device (RDD) or radiological emission device (RED)) is the sheer prevalence and use of radioactive materials in facilities like academic institutions and medical centers, which makes securing them difficult. Cultivating and promoting a robust facility nuclear and radiological security culture, combined with other physical protection systems can assist in the prevention of radioactive materials falling into the wrong hands. This promotion is highly dependent on a relevant self-assessment tool that would assess and correct deficiencies in the organizational security culture.

This paper investigates a series of culture indicators by assessing a wide-range of medical centers and academic institutions across the United States. The study uses a quantitative method of online surveys to measure current perceptions and identify areas of strengths and weakness in particular aspects of security culture. Respondents to the survey include technicians, nurses, and other authorized users of radioactive materials at medical centers and radiation safety staff and students from academic institutions. The study attempts to examine the influence of human factors in the current state of emergency preparedness, security violations, preventive education and training, policy, and management oversight. The resulting outcome of the analysis outlines appropriate recommendations for facility based security culture development, provides a process for raising security awareness, and promotes the sharing of best practices.

I. INTRODUCTION

Unfortunately, the threat of terrorism is real and may present in biological, chemical, or nuclear forms. Public exposure to radiation can result from a nuclear power plant event, the detonation of a nuclear weapon, or the release of a radioactive dispersal device (RDD). No critical infrastructures, including the universities and medical centers, are immune from accidents or deliberate incidents; however, the political and media responses to the incidents involving nuclear or radioactive materials are usually more intense than for any other type of accident or an act of terrorism. With universities and medical centers having an open access policy to members of the public, certain challenges are unique to these facilities and are often exacerbated by the ease of accessibility vs. strict security conundrum. The greater the lack of access control within the medical centers, the greater is the risk of theft and sabotage of radiological sources. Following the September 11, 2001 attacks, healthcare facilities and universities have taken measures and invested in securing high activity radiological sources through physical protection systems, access controls and other design basis threat approaches. However, over the years there have been many attempts globally to use radioactive materials in a dirty bomb or weapon of mass disruption (WMD). In

2019, researchers at the James Martin Center for Nonproliferation Studies (CNS) found 167 new incidents of nuclear and other radioactive materials outside of regulatory control globally, illustrating that nuclear and radiological trafficking remains a critical global security concern. As such, the high volume incident cases reported in the past several years have long provided the justification for an emphasis on security. Over half of all incidents reported involved what CNS classifies as "human failure", in which those responsible for radioactive material handling either acted carelessly or failed to adhere to the appropriate procedures. Incidents involving human failure show that even a well-designed facility can be degraded if the facility personnel responsible for implementing security systems or protocols are deficient. In this regard, basic standards of security culture should be understood by not only organizations but also the State as a whole to ensure adequate protection.

Over the past several years, the International Atomic Energy Agency (IAEA) has aggressively promoted the concept of "nuclear security culture" as a supporting tool to improve the physical protection systems of a facility. The IAEA defines nuclear security culture as "the assembly of characteristics, attitudes and behavior of individuals, organizations and institutions which serve as a means to support and enhance nuclear security". A cultural approach to physical protection involves a shared set of beliefs and attitudes established by an organization, and how these beliefs and attitudes manifest themselves in the behavior of personnel and formal working principles to provide adequate protection. The major premise of this paper is to understand the range of security requirements and the degree to which radiation safety personnel in the facility are aware of and committed to adhering to and promoting nuclear security culture. The purpose of this study is to provide a better picture of the extent to which nuclear security culture is part of an organization's culture. This involves making security recommendations, raising security awareness, and evaluating key indicators and characteristics of effective nuclear security culture.

Purdue University has been involved in conducting surveys since 2017 on radiation and non-radiation users across campus and other medical facilities. The survey questions were revised from the previous set of survey studies to gauge respondents understanding between the concepts of safety and security, emergency preparations, security violations and management oversight.

II. METHOD

The methodology employed survey assessment as a data collection technique. A list of 44 universities and medical centers was compiled based on the population density and institutional locations. An email requesting participation in the security culture survey was sent through a Listserv. A response rate of 6% was received from the radiological institutions who agreed to participate in the survey. The survey was completely anonymous and was taken only by radiation authorized users, i.e., personnel who are trained to work with radioactive materials. The survey consisted of 22-23 questions depending on the type of institution. The response options to the perception questions were 'strongly agree' to 'strongly disagree' on a five point Likert scale. During the data analysis, these response options were collapsed into three options (strongly disagree/disagree, not sure and strongly agree/agree). The major outcome variables included

measures of the organization's beliefs and attitudes, espoused values, and the perceived adequacy to respond to a security related threat.

The questionnaires for both radiological institution security surveys were categorized as per the International Atomic Energy Agency (IAEA) security culture model's categories of belief and attitude, principles and management systems, and behaviors of personnel and leadership. The security culture characteristic of management systems measured the perceived response on visible security policy, clear roles and responsibilities, operation and maintenance and training, and qualification. Leadership behavior included the survey statements regarding effective communication and motivation in improving the effectiveness of nuclear security.

The meaning and understanding of safety and security was also investigated in the survey. The question allowed a specific set of options (unintentional threats, intentional threats, safeguards, etc.) to be ranked and dropped in the box depicting a particular attribute or characteristic of safety, security or safety and security.

III. RESULTS AND DISCUSSION

This research initially wanted to investigate the radiological security culture from a cross-sectional representative sample of at least six universities and six medical centers across different regions of the US. With the participation in this survey being voluntary and without any tangible incentives, the response rate received was much lower than expected. Many emails and reminders were sent to various universities and medical centers requesting their participation in our security culture survey. The survey was available online for four weeks and a total of 37 radiation user responses were received. Of the 37 responses, 14 were the authorized radiation users from a university setting and the remaining 23 were the authorized radiation users from a medical center. Fourteen (51.83%) participants identified themselves as either physician, physicist, or a technician. Seven (58.34%) participants identified themselves as faculty, graduate student, or a radiation safety officer at the university setting. Three (11.1%) participants in the medical center survey identified themselves as security personnel. The undergraduate student and 'other staff' work classification category comprised a total of four (33.3%) university survey respondents.

The survey questions were broken into Likert scale questions, multiple choice questions and other forms of categorical scale options. Fig. 1 shows a variation in response to the subjective categorical questions on personal accountability, vigilance, and contingency plans and drills. The meaning of personal accountable behavior involves employees' understanding of their specific tasks and their ability to reliably deliver on their commitments. The survey participants, when asked about the standards of personal and collective accountability, gave a scattered response. Forty percent of the combined university and medical center respondents reported that they could not recall any action that they had taken to influence their peers in a way that would enhance security culture in the institution. The security culture indicator for vigilance of reporting any suspicious behavior in and around the institution was self-rated as 'highly likely' to 'somewhat likely', showing a vigilant attitude among the personnel. Drills and exercises were assessed as another way to reinforce the understanding of response procedures and identify deficiencies before an actual emergency occurs. A majority (62%) of the respondents noted that their institutions practiced emergency radiological

drills at least once per year, ensuring their familiarity with contingency plans and response functions.

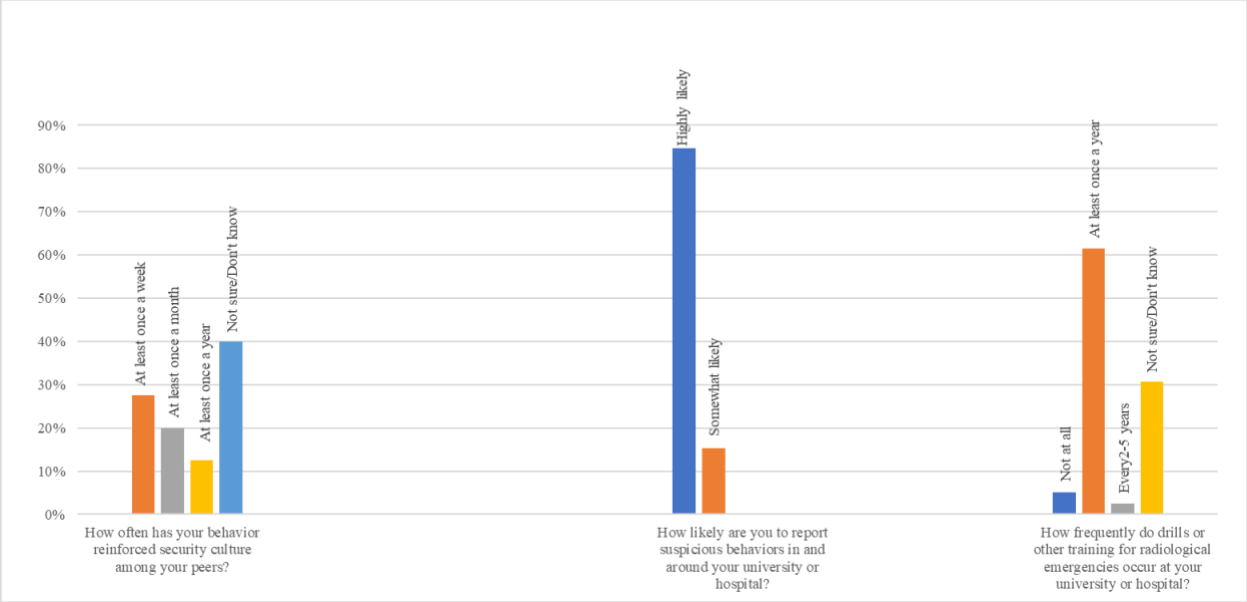

Fig. 1. Variations in the subjective categorical university and medical institution survey responses

In order to quantify the results of the questions that were common in both the university and the medical center survey, the Likert response scores were summed and divided by the number of respondents. Each survey statement was assigned a specific characteristic of an effective nuclear security culture. The characteristics of nuclear security culture are the beliefs and attitudes, behavior, and management systems; facilities that exemplify these characteristics will have more effective nuclear security (IAEA, 2008). Fig. 2 depicts the average score of each characteristic. A color code was applied based on the average score. A majority of the characteristic subgroups of clear roles and responsibilities, leadership behavior, awareness, visible security policy, motivation, and adherence to procedures fell in the green segment of the color coded graphical chart, signifying strong points that should be preserved and reinforced to maintain security culture. The characteristic subgroups of management oversight and transport of radioactive material indicated regions of weakness. The subgroup of management oversight was not found to be predominantly negative but merited some scrutiny as many respondents presented conflicting views.

The characteristic subgroup of management oversight was examined through indicators of workforce environment, reporting of serious concerns, and material control and accountancy. In the view of the potential vulnerability of radioactive material in transport, concepts of defense in depth and graded approach must be used to prevent the material from becoming vulnerable to malicious acts. Accordingly, the individuals involved in the movement of materials should have a clear understanding of the roles and responsibilities and must comply with effective routing schedules, security of passage, and other procedures involving the material transport. The mean scores from university respondents and medical center respondents on the knowledge of transportation of radioactive materials were found to converge.

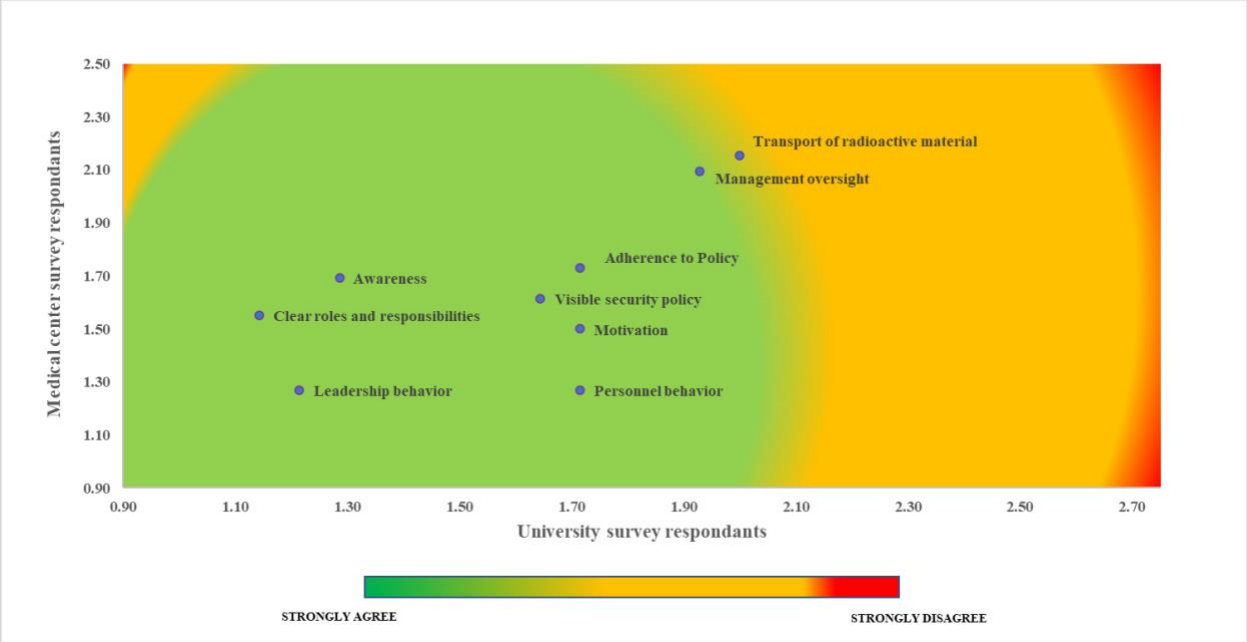

Fig. 2. Mean scores of characteristics of nuclear security culture by university and medical center respondents.

On further inspection of the responses received from the two faculties of participants on the material transport question, it was observed that a majority of the respondents with 10 or more years of experience with radioactive materials were well aware of the need for material transportation to be a secure process inside the institution (Fig. 3). None of the respondents had any negative views in regard to the nature of radioactive material transport. However, 15% of the total respondents from both institutions reported being unaware of the security measures taken during transport of radioactive sources. On comparing the sample mean scores for the awareness of transport security among the more experienced ($\geq 10\ years\ of\ radioactive\ material\ handling$) and the less experienced ($< 10\ years\ of\ radioactive\ material\ handling$) respondents across the two institutions, it was observed that the more experienced were much more aware of the secure process of material movement than the less experienced personnel. This lack of transport security knowledge among some users of radioactive materials could mean that internal source transfer awareness and training is only for a limited group of people (i.e., individuals who control the transport of materials).

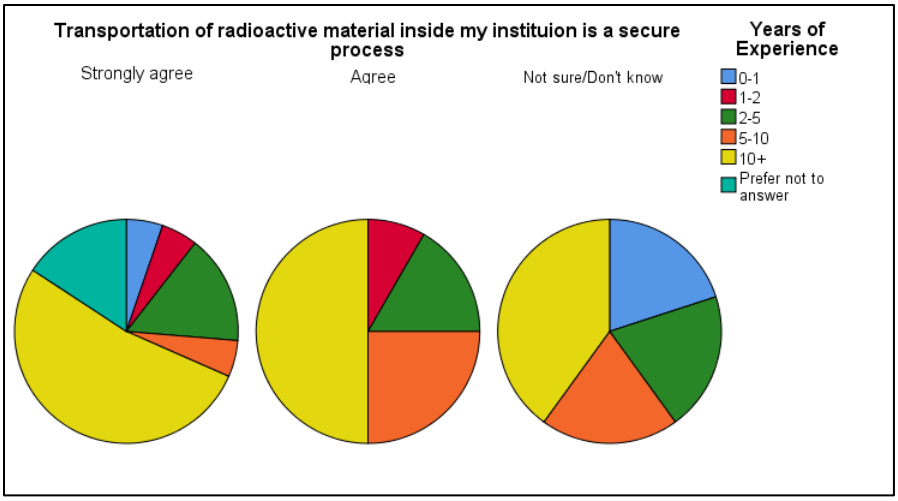

Fig. 3. Awareness of radioactive material transportation security among the respondents with different years of experience handling radioactive materials.

At large and varied institutions such as university or medical center, radiological security and culture are blended into an overall security regime. The security of a hospital for example is a collaborative effort, as the security guards or security system may not be exclusively responsible for all the components of the physical protection program and security management plan (Khripunov, 2019). In order to assess the challenges of a diversified radiological institution, the survey assessed the frequency of timely maintenance management, emergency preparedness and planning, types of restricted access controls, and employee motivational incentive programs to boost the effectiveness of nuclear security. Fig. 4 represents the percentage of total medical center survey respondents in each categorical question. Sixty nine percent of the respondents self-reported that the frequency of operational maintenance is mostly immediate and that the intended function of the system is not compromised. A strong consensus was seen among the respondents on the medical centers' access control systems, with a majority agreeing on badge as a common credential used for personnel entry control. Access control systems integrated with continuous surveillance provides balanced protection-in-depth at a facility. No respondents reported an absence of security cameras, entry controls or other surveillance systems in the facility.

Controlling who is in the medical center is a key security tactic. The level of visitation control at the entrances can both deter unauthorized visitors and minimize risk in multi-entrance medical centers. Sixty-nine percent of the respondents reported that visitors or patients' family members may only enter the radioactive material storage or usage area with an escorted authorized individual. A few respondents (11.54%) were unsure on the knowledge and recognition of the visitor management systems at the facility. Beliefs about the importance of access to confidential information being restricted to only authorized individuals were also assessed, with 96.15% of respondents taking an affirmative stand on the question (Fig. 4).

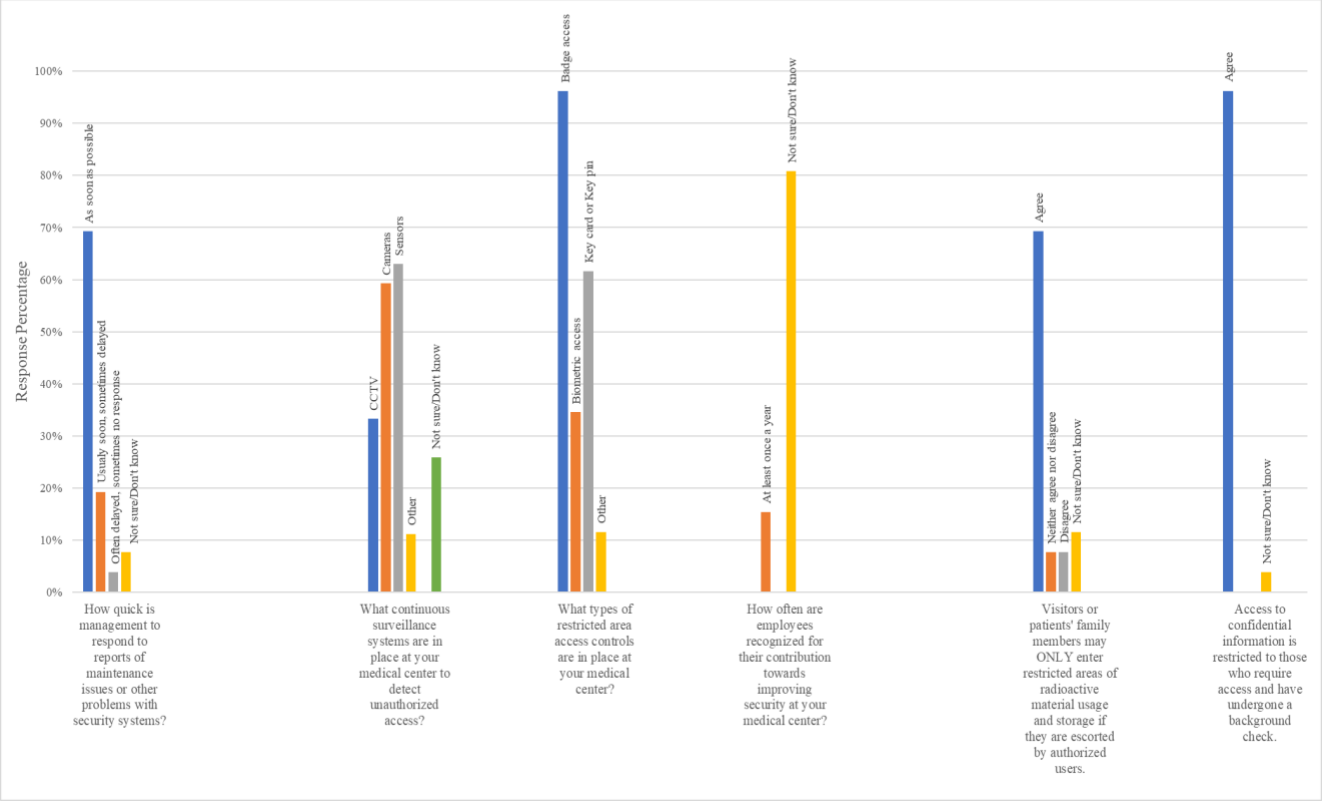

Fig. 4. Percent response of medical center survey categorical questions.

The concepts of safety and security have much in common, as they both consider the risk of human error. Nuclear safety refers to the protocols and proper operating conditions meant to reduce the nuclear and radiological risks to humans and the environment, whether they are caused by human errors or accidents, equipment failure, natural disasters, or other internal or external events. Nuclear security is concerned with the prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear or radioactive materials or their associated facilities (IAEA, 2008). Safety and security complement each other; in most cases they are not mutually exclusive but have to be managed in an integrated manner. In order to maximize the synergy and minimize the conflicts between the nuclear safety and nuclear security, it is essential for the authorized users to clearly understand and effectively implement the underlying attributes.

Measurements of the meaning of security and safety as perceived by the participants were assessed by gauging their understanding of certain keywords related to safety or security systems. Fig. 5 displays the percent response of each keyword/sentence item per categorical box of safety, security or safety and security. The discussion below presents the percent response received from the respondents on every item's association with safety, security or safety and security. The labels shown in bold represents their association with the specific domain as per the authors' perspective.

- *Unintentional threat:* Unintentional threats can be referred to as threats introduced without awareness, which may be caused from human errors, environmental hazards, or system failures. Unintentional threat may lead to a safety or a security related event. The most

common forms of unintentional threats may include security and safety issues arising from collapsing walls due to an earthquake or an employee accidently downloading a malware. Unintentional threats were perceived to belong in the category of safety by 25% of respondents, 31% of respondents ranked it in security category and 42% of respondents felt that unintentional threat should belong in the category of both safety and security.

- *Intentional threats:* These threats are the result of deliberate attempts to circumvent or defeat the systems' protection mechanisms or to exploit the vulnerabilities in such systems. Examples of intentional threats include identity theft, data breach, and sabotage of a facility. Sixty-one percent of respondents felt that the intentional threat should belong in the category of security, whereas 28% thought that it should belong in the category of safety and security. Very few respondents (8%) felt that intentional threats are exclusively a safety related issue, and one possible explanation for this result is that these respondents believe that safety alone fails to protect nuclear or radioactive material from theft, sabotage, or other illicit acts.

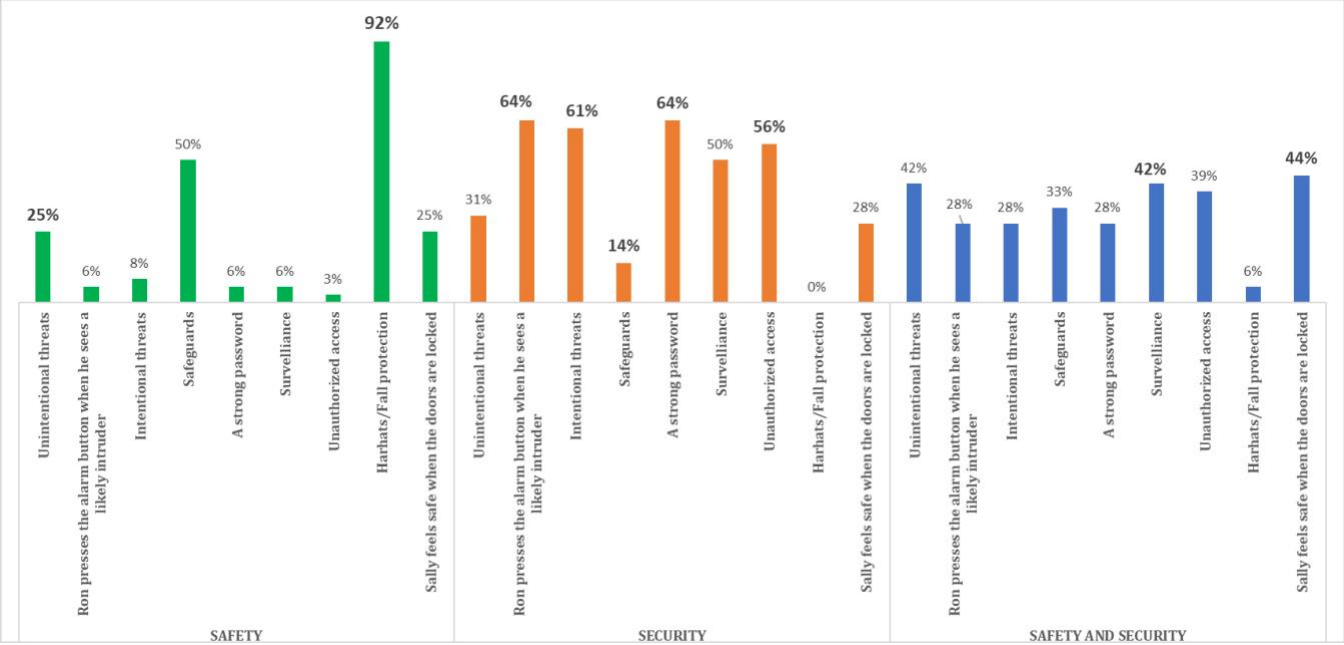

Fig. 5. The conceptual knowledge of safety and security among the university and medical center survey respondents.

- *Ron presses the alarm button when he sees a likely intruder:* This statement alludes to the importance of culture as an attribute of both organization and individual. Ron's prompt identification of an intrusion and proactive corrective action by pressing the alarm button, demonstrated vigilance in noticing and reporting potential security incidents and preventing the threat. The spread of responses reported from the respondents were quite similar to the spread of responses received on the keyword item of intentional threats. Many (64%) reported that this statement should be included in the category of security. Likewise, we think that the statement is a clear security culture indicator where a staff member understands that security depends on the vigilance and observational skills of personnel.

- *Sally feels safe when the doors are locked:* The act of locking the door can be described as security. Locking the doors makes Sally feel emotionally safe (and secure), showing how easily the ordinary use of the words "safety" and "security" can be confused with the technical definitions of facility security and occupational safety. Although Sally feels safer after the doors are locked, from the standpoint of occupational safety, the effect is neutral or she is possibly rendered somewhat less safe. It can be argued that sometimes locked doors and restricted access controls in facilities like nuclear power plants can be a safety hindrance; should an emergency occur, these areas would require accessibility to facilitate evacuation of personnel. According to the survey, 44% respondents said that this example statement is related to both safety and security. An almost equal number of respondents identified this item to fall under the safety category and security category, respectively.
- *A strong password:* A strong password is a clear security indicator. Compromised passwords give cybercriminals an open door to attack and hack your personal accounts. Sixty-four percent respondents felt it belonged in the security category.
- *Surveillance:* The term surveillance in security implies the monitoring of behavior, activities, or information for the purpose of detection and risk mitigation. The primary function of surveillance systems is to intercept a likely intruder or monitor for other malicious acts. In many organizations video surveillance also provides a definitive means to verify and validate employee's adherence to procedures to better control employee safety, identify workplace injury and the potential hazards that may exist within the environment. A majority (51%) ranked surveillance as purely security category.
- *Hardhats/Fall protection:* Hardhats are a necessary head protection in work environments, which purely falls under the safety category. A high percentage (91%) of consensus was seen from the respondents favoring this response as well.
- *Safeguards:* Safeguards as per the IAEA is defined as a set of technical measures that are applied on nuclear facilities and material to independently verify a State's legal obligation that nuclear facilities are not misused, and nuclear material is not diverted from peaceful uses. The safeguard systems are implemented to deter and detect the diversion of nuclear or radioactive materials. With survey respondents ranking safeguards as majorly (51%) a safety concept, shows that the term safeguard is not as easily understood outside of restricted groups with specific expertise in the nuclear industry. This informational gap exists because there are no suitable parallels in other industries. Safeguards have more commonality with security than it does with safety.

IV. CONCLUSION

The overall objective of this study is to reveal the current status of nuclear security culture at radiological institutions such as universities and medical centers across the United States and to identify factors that influence an institution's attributes and policies on the aspects of nuclear security. This paper presents the preliminary results of only two radiological institutions who showed interest and agreed to participate in our survey. The average scores of characteristics of nuclear security culture received from two faculties of respondents (university and medical center) were compared. Among the nine characteristic subgroups assessed, both of the institutions showed

good security culture traits, with their reported mean scores being less than 3. A few respondents across the university and the medical center reported an unawareness of the security of the transport of radioactive materials. The respondents with less than 10 years of experience in handling radioactive materials showed less awareness than the group with more than 10 years of experience. The gap in training and awareness could mean that the assessed radiological institutions believe in using a targeted approach to train and educate only those individuals who are responsible for the movement of radioactive material inside the facility.

The survey also gauged the understanding and the knowledge of the difference and similarities between the concepts of safety and security among the respondents. A majority of the respondents had a hard time distinguishing between a few specific connotations that are not shared between the two fields of security and safety. There is a consensus in the scholarly and professional literature that the difference between security and safety lies in whether the incident was inflicted intentionally or not, characterizing safety as being accidental (unintentional) and security as being intentional or deliberate (Jore, 2019). From this division between safety and security, perpetrators with malicious intent of causing harm such as a hacker or terrorist can be categorized as a security threat, while a worker abusing drugs or violating a safety procedure leading to a major accident can be categorized as a safety threat. The high variation in the respondents' answers for the keyword items of intentional and unintentional threats, safeguards and surveillance may indicate that many professionals have an ambiguous understanding of the concepts of safety and security. A recommended approach to enhance awareness would be educating the staff members with an understanding of the rationale, the basic principles, and the terminology regarding safety and security of radioactive materials.

V. REFERENCES

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