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Review Article

Effective Factors in Improving the Emergency Department Preparedness of Hospitals in Radiation and Nuclear Incidents and Nuclear Terrorism: A Systematic Review

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Abstract

Background: Due to existence of nuclear power plant sites in various parts of the world, as well as political threats in disaster-prone areas throughout the world, there is a probability of nuclear and radiation incidents. The present study aimed to extract effective criteria in emergency department preparedness of hospitals in radiation, nuclear incidents and nuclear terrorism in different countries around the world.

Methods: A systematic search was carried out in Cochrane Library, PubMed, Scopus, Science Direct, Web of Science, ProQuest and Embase databases between Jan 1970 and Jul 2018. The systematic search was carried out according to the PRISMA standard. The required information was extracted from the papers based on the abstract and collection form.

Results: Overall, 1091 papers were finally extracted. The initial search included research papers. After reviewing the papers' titles, abstracts and full texts, 15 papers were selected for final analysis. Next, 32 criteria were extracted. The criteria were divided into 3 categories. The categories included staff, stuff and systems (structure). The most frequent criteria included training criteria, personal protective equipment, decontamination and practice.

Conclusion: The results of the systematic review provided an overview of the effective factors in improving the emergency department preparedness during radiation and nuclear incidents. In addition to the mentioned criteria in different studies, other hidden factors affect the emergency department preparedness in radiation and nuclear incidents. Thus, the highest level of preparedness should be considered.

Keywords: Preparedness; Emergency department; Hospital; Radiation incidents; Nuclear incidents; Terrorism

Introduction

The application of radiation and radioactive material has developed significantly because of technological progress. Ionizing rays, including X-rays and gamma rays, and beta and alpha particles, have the ability to ionize the material, which can be the cause for chemical changes in DNA and cell death (1). Different incidents such as Three Mile Island and Chernobyl are examples of these incidents that have led to environmental contamination and damages.

Natural and man-made disasters can cause erratic release of dangerous and nuclear contaminants, as the Fukushima Daiichi nuclear disaster occurred after a magnitude 9 earthquake, which triggered a tsunami in 2011. Nuclear incidents in the form of war, terrorist operations, or atomic and nuclear incidents can lead to intense radiation and various diseases, including acute radiation syndrome(2). Exposure to radiation causes a rapid decrease in blood lymphocytes, which is an indicator for possibility of hemodynamic assessment as a reliable tool for assessing these people(3). This indicates that a quick assessment of populations exposed to radiation is essential and will avoid aggressive behavior. Moreover, there is a fear of being contaminated with radiation among health care providers, hence, the mental health needs of these people meet(4). Acute radiation can lead to hematologic, gastrointestinal, cardiovascular, skin syndromes and even several type of cancers. Triage, antidote injection and decontamination should be done as soon as possible(5).

For a proper function of healthcare and improving it in critical situations, hospitals need to understand these conditions and have a plan against incidents and crises. These plans should be based on identifying vulnerabilities(6). Hospitals can respond properly to emergency situations with preparedness plans and training(7). In this regard, some studies have considered the training needs in case of nuclear incidents for medical centers(8). Respond planning should be done with the participation of doctors and nurses along with the radiation safety officer or medical physics specialist(4). Medical centers must be prepared for different aspects, such as equipment, training, communications, etc., during nuclear disasters(9). Hospitals need special equipment and facilities, such as dosimeters and protective suits to detect actual radiation incidents, not only to prevent more mortality from exposure but also to provide hospital personnel with adequate protection from radiation(10). In the United States, a specific system, which includes a special triage for radiation incidents, treatment and transfer has been designed to provide treatment for people exposed to radiation(11).

Due to existence of Nuclear Power Plant (NPP) sites in various parts of the world, as well as political threats in disaster-prone areas throughout the world, there is a probability of nuclear and radiation incidents. The present study aimed to extract effective criteria in Emergency Department (ED) preparedness of hospitals in radiation, nuclear incidents and nuclear terrorism in different countries around the world.

Methods

Eligibility Criteria and Search Strategies

The study protocol was first registered in PROSPERO database with identification number CRD42018102815.

The systematic search was carried out according to the PRISMA standard. PRISMA is a set of screening and extracting information from articles for the systematic study, which is the most authoritative tool for evaluating articles that the Cochrane database also uses. For extracting relevant studies, a systematic search was carried out in English peer-review texts from Jan 1970 till the end of Jun 2018 related to the research question, "What factors have other studies identified about emergency department preparedness of hospitals in radiation incidents?" A quick and comprehensive search on the Cochrane Library site was carried out based on similar systematic

papers in order to ensure that there was no systematic review in this field. This database did not find any similar paper; hence, the search was carried out on Scopus, PubMed, Cochran Library, EMBASE, ProQuest, Web of Science, Science Direct databases. The Federal Emergency Management Agency (FEMA), the International Atomic Energy Agency (IAEA), the Pan American Health Organization (PAHO), WHO, and the Google Databases were also used to find relevant reports and guidelines. The search for Gray Literature was also carried out on Internet sites, books, dissertations and conference papers. The search was carried out in "abstract", "title" and "keywords" of papers in different databases. The subject headings in MeSH were used to find papers in the PubMed database (Table 1). Since there was no comparison group; hence, C or comparison group was not considered in PICO. Papers were selected based on search keywords by two authors. Finally, the criteria were extracted from the selected papers. A complete list of references from all papers was prepared in the next step, the title of the papers was reviewed by the researchers, and the papers that were not related to the purpose of the study were eliminated. All the search procedures were repeated to increase our confidence. Reference Management was done using EndNote X8.1.

Table 1: The Utilized Search Strategy Based on Effective Factors in Improving the Emergency Department Preparedness of Hospitals in Radiation Incidents

PICO	*#1 AND #2 AND #3*	*Strategy*
P	Hospital OR Emergency department OR Emergency Ward OR Emergency Service OR Emergency Unit	#1
I	Nuclear Disaster OR Nuclear Catastrophe OR Nuclear Emergency OR Nuclear Accident OR Nuclear Incident OR Nuclear Event OR Radiation Disaster OR Radiation Catastrophe OR Radiation Emergency OR Radiation Accident OR Radiation Incident OR Radiation Event OR Radiation Exposure OR Radiation Terrorism Disaster OR Radiation Terrorism Catastrophe OR Radiation Terrorism Emergency OR Radiation Terrorism Accident OR Radiation Terrorism Incident OR Radiation Terrorism Event OR Nuclear Terrorism Disaster OR Nuclear Terrorism Catastrophe OR Nuclear Terrorism Emergency OR Nuclear Terrorism Accident OR Nuclear Terrorism Incident OR Nuclear Terrorism Event OR CBRNE OR CBRN OR CBR OR CBN	#2
O	Preparedness OR Preparation OR Readiness	#3

Inclusion Criteria

Each of the titles of articles was read by two experts and if there were at least two items in the title from the 3 main search strategies, that article was selected. The abstract of the papers was selected based on the fact that at least one component of emergency department preparedness of hospitals in disasters based on 3S (staff, stuff, system) should be included in the title, keywords or abstract of the paper. The search for this systematic review was retrieved amongst papers between 1970 until 2018. Quantitative and qualitative papers were selected. There were search keywords in abstract, title or keywords. Papers should be relevant to the research question. Scientific papers had to be published in journals reviewed by peer review.

Exclusion Criteria

Papers that referred to irrelevant variables to the research question of this study, as well as papers that were not available in full text, were excluded.

Screening

The title of all papers and reports from sites and databases were first reviewed by two authors. Papers that were relevant to the research question

and had the inclusion criteria were selected. In the next step, abstracts of selected papers and reports were read by two authors. Then, the papers that were completely in line with the purpose of this study and the inclusion criteria were selected and the full text of the paper was read and assessed by two authors. Finally, papers that referred to the criteria and effective factors improving the emergency department preparedness of hospitals in radiation incidents were selected. The assessment of these papers was carried out by PRISMA standard. Furthermore, publication bias and citation were also considered, and most cited papers were also carefully reviewed. This means that articles with high citations and articles with meaningful results were carefully reviewed by experts. To not be affected by these bias.

Data Extraction

The required information was extracted from the papers based on the abstract and collection form. This form includes the corresponding author, study population, study sample, study time, study design, data collection instrument, methodology, results, limitations, conclusion and the effective factors on preparedness. The abstract forms were completed for each selected paper. When finished, the items of all forms were synthesized and displayed in descriptive tables. This step was also carried out by two researchers. Finally, other authors also commented on contradictory issues. These forms were made in Microsoft Word.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

Results

After searching the databases, 1091 papers were finally extracted. However, 181 were excluded because they were repeated in different databases. Overall, 781 papers were excluded by reviewing 910 papers, since they were inconsistent with the purpose of the study. Abstracts of 129 remaining papers were studied from the previous stage and 88 papers were excluded because they were inconsistent with the purpose of our study. Finally, 25 full-text papers were selected. Fifteen papers were completely consistent with the purpose of our study. Figure 1 shows the final paper selection.

The synthesis of the selected papers' results is shown in Table 2, based on the frequency of papers. Accordingly, the criteria were divided into 3 categories of stuff, staff, and system (structure). The most frequent criteria in terms of repetition were education criteria (cited in 13 papers), personal protective equipment (cited in 12 papers), decontamination equipment (cited in 11 papers), and training (cited in 10 papers).

Discussion

The purpose of this study was the extraction of effective criteria in improving the emergency department preparedness of hospitals in radiation and nuclear incidents and nuclear terrorism in different countries around the world. Eleven studies were quantitative and had measured the preparedness in radiation and nuclear incidents through a questionnaire. However, 2 papers were qualitative that was carried out by experts in the field of man-made disasters, radiation incidents and interviews with key informants, as well as focus group meeting. Many studies reported different factors for the preparedness in these incidents, which differed substantially, but in most of these studies, there was a mutual agreement that staff was the most important factor in preparedness (15,16,18,25). Five studies were extracted in the United States (16,23, 25, 26, 28).

According to the occurrence of Three Mile Island accident in 1979, organizations and research institutes have conducted extensive surveys and studies on the issue of preparedness in radiation and nuclear incidents.

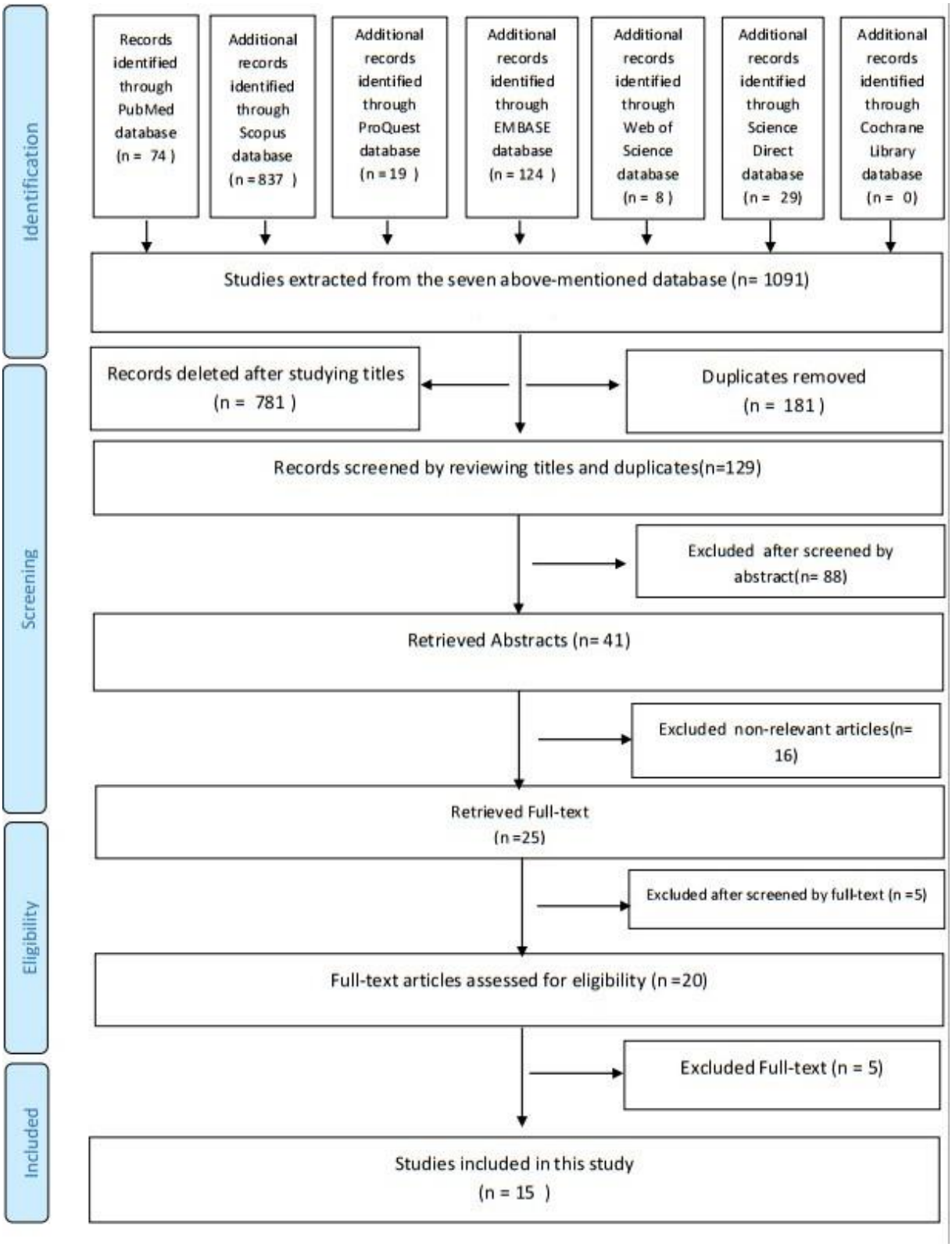

Fig. 1: PRISMA flow diagram for the systematic review process
Altogether we selected 13 Original (12-24) and 2 Review papers (25, 26)

Table 2: Effective factors in improving the emergency department preparedness of hospitals in radiation and nuclear incidents and nuclear terrorism

Category	*Criteria*	*Frequency*	*References*
Staff	The presence of 24/7 nuclear specialists	3	(12-14)
	Education	13	(12-24)
	Risk perception	2	(12, 16)
	Support, safety and communication with family and loved ones	3	(13, 15, 17)
	Mental health needs of staff and patients and presence of psychologist	4	(13-15, 24)
	Having a nuclear triage team	3	(14, 20, 21)
	Having a nuclear decontamination team	9	(12, 14, 15, 17, 20, 22-25)
	Awareness, competence and knowledge	2	(14, 19)
	Staff security	1	(14)
Stuff	Personal protective equipment (PPE)	12	(12, 14-17, 19-21, 23-26)
	Radiation detectors	8	(12, 14, 15, 17, 18, 20, 25, 26)
	Antidotes and chelating agents	7	(12, 14, 15, 20, 24-26)
	Decontamination equipment	11	(12-15, 17, 20-23, 25, 26)
	Medications	4	(13, 14, 22, 24)
	Resources (bed)	1	(26)
System(Structure)	Isolation	1	(12)
	Disasters plan	8	(12, 14, 16-18, 20, 23, 26)
	Treatment protocol	2	(13, 17)
	Guidelines	1	(13)
	Care treatment	1	(13)
	Reliable information sources	3	(14, 15, 17)
	Proper ventilation	1	(16)
	Communications	4	(13, 14, 17, 22)
	Training and Exercise Program	10	(13, 16-20, 23-26)
	Team-based approach	1	(14)
	Unity of command	1	(21)
	Waste management and sewage treatment	3	(21-23)
	Allocating places for worried people, infected and non-infected people	1	(14)
	Trauma care system	1	(14)
	Risk appraisal	2	(14, 26)
	Security	1	(22)
	Allocating a place inside or outside the emergency department for decontamination	10	(12, 14, 15, 17, 20-23, 25, 26)

Following the United States, other studies were conducted in Canada, Australia and other European countries, particularly Belgium. Since there are nuclear reactors and facilities in these countries, it is considered as high risk, and researchers are encouraged to do research in this regard.

After analyzing and extracting the data from the final studies, the preparedness factors were divided into three general categories of stuff, staff, and system (structure). The important factors are explained in each category. Staff should have adequate physical and mental preparedness to respond to such incidents. In fact, staff is the most important part of the response to radiation incidents. However, the vulnerability of staff should be reduced by increasing the capacity. Nuclear

medical specialists should be present at the emergency department 7 d a week/24 h a day. In case of incidents, they should give technical and specialized consultations to treatment staff. In terms of exposure to injuries and hazardous conditions, the safety and health of ED staff is the main priority. Staff are responsible to take all necessary measures to treat patients, unless their lives are compromised.

At the time of this accident, emergency staff in the emergency department are constantly worried about their families and loved ones and might not have sufficient focus and attention to care for the injured (15,16). Staff should be able to communicate with their families and loved ones by phone and be aware of their health status in order to do their duties calmly.

Many people move toward the ED after radiation and nuclear incidents and have a lot of fears that they might have been contaminated with radiation. Therefore, the presence of a psychologist in the ED is critical (27-29). ED staff may also suffer from the psychological symptoms of these incidents. The psychological effects of radiation accident on the response and medical staff depends on various factor, including the ability to cope with stress and personality traits. Psychologists can contribute to calm the injured people and treatment staff, and more care must be provided for those with acute psychological symptoms. Safety and security staff in ED play a critical role in regulating and controlling traffic.

Hospitals' crisis committee should provide the ED staff with training on radiation and nuclear incidents by providing staff with proper training, they could respond properly to such incidents and increase their perceived risk toward radiation and nuclear incidents (15, 18, 27). ED staff's perception of the occupational risks has a significant impact on their safety behavior in the hospital environment.

Several teams in ED have to be formed to respond properly to radiation and nuclear incidents, including the victim delivery and transfer team, emergency preparation team, surveillance and triage team, decontamination team, Para clinical service team, documentation team, the team for decontaminating spaces and equipment, and the team for handling contaminated corpses(8). In some cases, the collaboration of specialized teams outside the hospital might also be used.

The members of nuclear triage team and decontamination team should be formed separately in the emergency department. As long as it is possible, the members of this team should not be part of the ED and should be formed independently (14, 20, 21, 28). Triage is different from conventional triage in radiation and nuclear incidents, these specialized teams of triage should be equipped and always ready. Training and periodic training will enhance the ability of these teams (16, 17, 22).

The next category is stuff that represents the equipment and facilities required by the ED of hospitals during such crisis. Personal protective equipment (PPE), radiation detectors including Geiger-Muller, scintillation counter and personal dosimeters in the ED should be included. The whole ED staff should be trained to properly wear the PPE (14,16). The wounded or infected people are measured with these detectors, and the amount of radiation received by the individual is determined and according to the amount of radiation received, the priority of the therapeutic measures is carried out. Antidotes and chelating agents, medications and supplies, such as beds, should also be anticipated in the ED. Because the immediate treatment of these injured is of high priority (15, 20, 24).

The next category is the system (structure) that represents the system and structure required by the emergency department. People who have received a very high degree of radiation should be isolated in an especial place at ED, and assigned as soon as possible. Protocols, guidelines, and the response to such incidents should be determined and developed prior to the occurrence of these incidents, in order to provide a comprehensive and integrated standard for the treatment of infected people, since the quick and precautionary measures of the first condition in response to this kind are the top priority in these incidents. ED

needs to continuously obtain the necessary information about the incidents from the operations control center and the hospital's crisis committee, therefore, risk communication and using the reliable information sources play a key role in responding to these incidents, and before the accident occurs, the organizations and departments must be involved in obtaining and providing continuous information. During these incidents, quick access to additional information is of high significance. For instance, type of radiation and the distance between the accident and the hospital should also be considered. Information resources can also be obtained from local police agencies, fire station and EMS. Launching hotlines is also very helpful.

The most important component of preparedness in radiation incidents is exercise and training. The exercises are carried out in three different ways, tabletop, computerized, and real simulation. Periodic training should be carried out at least 2 times a year in order to increase staff preparedness and subsequently give a proper response to these incidents. Table training are the most accurate and low-cost types of training. However, real training are costly and people should respond realistically to hypothetical incidents. All three types of training should be carried out alternately and should be codified in the ED (27,28).

Incident command system (ICS) is a structure for coordinating the response in incidents. The ICS should be established in ED and the responsibilities and successor of each section should be identified. The ICS should be developed separately in the ED, although the ICS of the entire hospital is also available, in some cases, ICS is only activated during emergency (21).

Different spaces, including ambulance station and victim delivery, personal protective equipment, non-contaminated radiation exposure area, inspection area and injured triage, place to handle healthy people, decontamination area, contaminated space, equipment collection area and the contaminated waste, the shower for the outpatient ward and the bathroom for the medical staff at ED are required (10). These spaces should be built and set up during the preparation phase.

Hospital facilities are at risk for nuclear and radiation incidents, and the best way to prevent pollution is to investigate and monitor the severity of ED. Hospital emergency departments are the gateway for patients' entrance to the hospital, and if the appropriate follow-up measures are not taken, there is a potential for contamination of other sections. Human resources are the most important resources in the emergency department of hospitals. Surge capacity is one of the most important measures to increase preparedness when exposed to radiation incidents. Emergency department staff should be familiar with methods and approaches to increase surge capacity (29). Although significant progress has been made regarding the preparedness of ED hospitals, there are still many obstacles and challenges.

In response to radiation incidents, coordination and collaboration between and within the organization is required. Therefore, prior to the accident, there should be appropriate coordination between the trustees in responding to such incidents. Policy makers should pay more attention to the issue of radiation and nuclear incidents. Because such incidents can occur in any place at any time. The government's financial support can solve many problems in equipping and preparing the EDs in hospitals.

Several studies have reported relatively similar factors in terms of preparedness for radiation incidents (21,25,28). Hence, the results of this study can be used to develop a comprehensive tool for assessing emergency preparedness of hospitals in radiation, nuclear incidents and nuclear terrorism.

Limitations

The present study has one limitation. Only English language papers were selected.

Conclusion

The results of this systematic review provide an overview of the effective factors in improving the hospital emergency department preparedness during radiation and nuclear incidents. In addition to the criteria mentioned in various studies, other hidden factors that affect the preparedness of hospital emergency departments in radiation and nuclear incidents. Hence, maximum preparation should be taken into account.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interests

The authors have no conflict of interest to declare.

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