RADIATION PROTECTION ASPECTS OF THE NEW WHOLE-BODY RTG SCANNERS

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Abstract

This paper summarizes the recent situation regarding the design and construction of the new whole-body security rtg scanners which are being installed at some airports for passenger security control. Special attention is paid to assessing the exposure associated with this screening in terms of the effective dose resulting from one examination. Based on an estimated number of passengers and the data from manufacturers, a collective effective dose is estimated. Then, a total number of additional cancer cases (besides their spontaneous occurrences) can be calculated and compared with the risk which can be avoided when this sophisticated equipment is used for the security screening of persons. Preliminary results have shown that this technique can be considered justified under the assumption that there is still a real potential threat of radiological terrorism. This conclusion relies on the data about the effective doses given by manufacturers which, however, may not always be accurate. Additional efforts have to be aimed at reliable testing and QC of new scanners in order to establish more precisely their radiation protection characteristics.

Key words

Security, rtg scanners, airport, exposure, terrorism

1. Introduction

Recently there has been a lot of commentary at various levels both in scientific journals and in the public media about the potential harm of new roentgen (rtg) whole-body scanners, and their safety has been questioned and openly challenged even by reputable scientists.

The present philosophy of radiation protection is clearly based on a generally agreed and accepted assumption that all exposures, no matter how small, may be associated with some potential health effects the probability of which is a linear function of the exposure. This well-known approach relies on the NLT (non-linear threshold) relationship between the exposure and the occurrence of stochastic effects.

Taking this into account, it goes without saying that rtg scanners also contribute a certain effective dose to those who are examined by such machines. If this relatively very low effective dose is obtained by a large number of persons, due to the collective effective dose (which will not be negligible) some additional cancer cases among exposed people will appear at some time in the future. Although this number of cancers induced by the exposure of screened passengers is not comparable to the spontaneous cancer rate occurrence, which may be something like 20-25%, the damage in terms of several tens or hundreds of cancer cases caused by rtg scanners should be carefully compared with the

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possible benefit. This positive effect is associated with the prevention of the number of casualties due to an attack on a civilian airplane where terrorists succeed only because there was no strict screening of passengers aimed at preventing the smuggling of dangerous objects or material on board.

This issue is the most important in deciding whether this new technology for security screening can be fully justified.

The stricter demands and requirements were introduced after the terrorist attacks on the USA on September 11 in 2001 (Figure 1) [1]. These were so far the most tragic malevolent acts, where nearly 3000 people died, including all passengers and crew members on four hijacked aircrafts and people on the ground.

Figure 1. United Airlines flight 175 crashes into the south tower of the World Trade Center in New York City.

2. Number of air passengers and airline accidents including their causes

In accordance with the latest information maintained by the IATA (International Air Transport Association) [2], despite the worldwide crises affecting economies and business, the total number of passengers has continued rising: in 2009 almost 2.3 billion and in 2010 about 2.4 billion; these figures are far higher than for 2001, when the number of passengers was 1.6 mil. The number of fatal accidents and total fatalities in these years were as follows: in 2001 - 25 fatal accidents with 749 fatalities; in 2009 - 18 fatal accidents with 685 fatalities; and in 2011- 23 fatal accidents with 786 fatalities.

It is estimated that the number of air passengers in the USA using domestic and international travel on US airlines was about 660 mil in 2010, while in 2011a small increase was recorded to approximately 670 mil. Some idea about the situation can be obtained from available statistics summarizing accidents and their causes regarding the transport of passengers by air (Table 1).

Table 1. The accident summary based on 1,085 fatal accidents involving commercial aircraft, worldwide, from 1950 through 2010 for which a specific cause is known. The data do not include aircraft with 18 and fewer people aboard, military aircraft or helicopters (based on the data available from PlaneCrashInfo.com [3]).

Cause of fatal accidents	Fatal accidents by decade (percentage)						
	1950s	1960s	1970s	1980s	1990s	2000s	All
Pilot error	41	34	24	26	27	10	29
Pilot error (weather related)	10	17	14	18	19	19	16
Pilot error (mechanical related)	6	5	5	2	5	5	5
Total pilot error	57	56	43	46	51	54	50
Other human errors	2	9	9	6	9	5	7
Weather	16	9	14	14	10	8	12
Mechanical failure	21	19	20	20	18	24	22
Sabotage	5	5	13	13	11	9	9
Other causes	0	2	1	1	1	0	1

Accidents involving airliners transporting hundreds of millions of passengers every year had occurred, are occurring and will occur in the future. In principle, we cannot reduce the accident probability or risk to zero. The aim is to limit the number of such cases to the possible minimum taking into account social and economic circumstances. It is obvious that protection has a cost and, with the limited resources at our disposal, society has to optimize any preventive measures introduced in order to ensure adequate safety. Here adequate safety means safety at the level of the safety in other areas of life where we deliberately accept some reasonable risk.

In general, airline accidents have occurred primarily because of technical failure, pilot and other human errors (on average more than 50% of cases), weather, and also because of malevolent actions, including sabotage committed by terrorists who succeeded to smuggle on board appropriate means for committing such crimes (about 10% of all fatal accidents). Obviously, any screening can only reduce the risk of accidents where a terrorist attack is the cause. In fact, a terrorist attack can occur at any stage when passengers are on board, including during taxi, loading/unloading, parking or towing. Moreover, in assessing the total impact of any airline accident, one has to also consider casualties on the ground as a result of such an event.

IATA has two objectives for security: to make the system convenient for passengers and more effective at finding terrorists. Each security crisis has resulted in new rules and added layers of process and bureaucracy. An overall review of developments is essential, along with a focus on a radically different checkpoint of the future (Figure 2).

The situation in Europe was that just under 800 million passengers were carried by air in 2010 in the EU-27 (Figure 3) [4]. The number of air passengers carried in the EU-27 had stagnated in 2008, fell by 5.9 % in 2009, and rebounded by 6.0 % in 2010.

Figure 2. The IATA vision of checkpoints of the future [2].

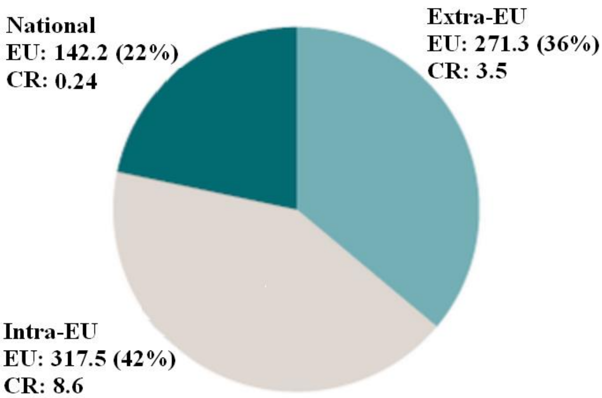

Figure 3. Overview of the EU-27 air passenger transport in 2009 (in mil) together with the data from the Czech Republic (CR) [4].

3. Principles of whole-body scanning and resulting exposure

Security systems are required to detect contraband, weapons, explosives, and other dangerous objects concealed under clothing. Metal detectors and chemical sniffers are commonly used for the detection of large metal objects and some kinds of explosives; however, a wide range of dangerous objects (including plastic and ceramic weapons developed by modern technology and other non-metallic objects) exist that cannot be detected with these devices.

This is why a new backscatter whole-body scanner was developed at the beginning of the 1990s which was aimed at detecting objects concealed on persons.

The principle arrangement of such a scanner based on the original patent drawings is illustrated in Figure 4 [5].

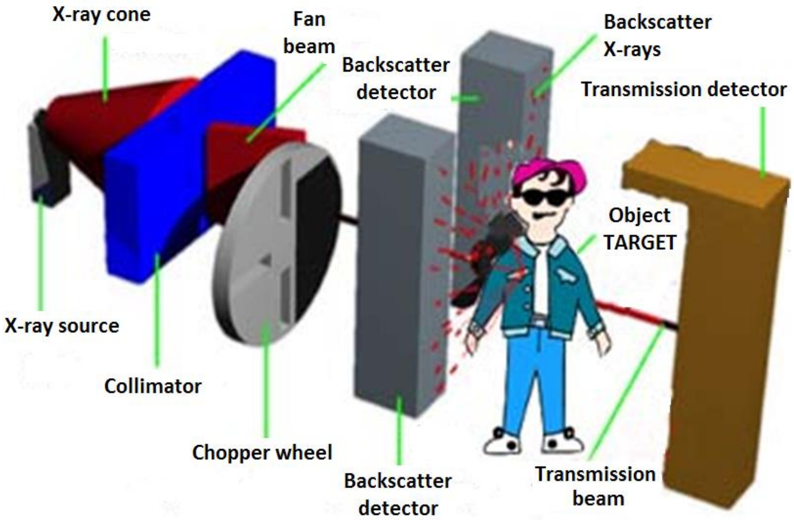

Figure 4. Principle of a whole-body rtg scanner including its practical arrangement (based on the original patent [5,6] and its graphical illustration [5,6].

A narrow, pencil-tip-sized beam is directed toward the subject, X-rays are backscattered from the subject to detectors, which receive the backscatter signal or X-ray reflectance. In this manner, the backscatter signal of each point on the body is measured and recorded in the digital computer which produces an image on a monitor.

The actual design of the rtg scanner of a leading manufacturer of this high-tech security equipment, Rapiscan Systems [7], including the resulting image, is illustrating in Figure 5. Rapiscan Secure 1000 Single Pose whole body rtg scanner which can detect small objects and threats concealed on a passenger including organic and inorganic threats, metals and non-metallic objects. With one system, customers can detect concealed liquids, ceramics, weapons, plastic explosives, narcotics, metals, contraband, currency etc.

a) b)

Figure 5. Rapiscan 1000 security scanner, a) an overall view, and b) an official inspecting the image [7],

The backscatter technology is based on the Compton scattering effect of rtg photons. Unlike a traditional rtg machine which relies on the transmission of photons through the object, backscatter photons which reflect from the object are detected and an image is produced by means of a computer. The backscatter pattern is dependent on material properties and is efficient for imaging objects with different Z, including organic materials.

4. Health consequences in terms of additional cancer cases

The measure of the health detriment at low exposures can be quantified by the effective dose from which using the relevant risk factors one may assess the impact of the exposure of a large enough group of exposed persons in order to find among them the additional number of cancer cases.

The effective dose, E, is defined as a double sum based on the average absorbed dose, $D_{T,R}$, in an assumed organ or tissue T due to the radiation type R weighted by an appropriate radiation weighting factor, w_R, and tissue weighting factor, w_T, i.e.

$$E = \sum_T w_T \sum_R w_R \, D_{T,R}$$

Obviously the effective dose cannot be measured directly but it may be assessed based on the calculation when all necessary details of the irradiation conditions are known or can be approximated by some operational quantities such as the ambient dose equivalent, directional dose equivalent or personal dose equivalent. These quantities are measurable and give a reasonable estimation of the effective dose due to the external radiation [8,9].

In the case of exposure received by a passenger checked by a whole-body rtg security scanner, the situation is rather complicated because of very specific irradiation conditions and geometry. This may lead to unreliable results in the assessment of the effective dose. It is believed, however, that this dose lies in the range 0.01-0.1 µSv per a single scan [7,10,11].

Based on this assumption, where some more detailed measurements should be performed in order to obtain more reliable information about the exposure, the number of additional cancer cases N_{cc} above the natural or spontaneous incident of this disease can be assessed using the relevant conservative detriment-adjusted nominal risk factor f_c for a fatal cancer and the collective effective dose S, or

$$N_{cc} = f_c \, . S$$

the collective effective dose S being defined as

$$S = \int_E E \frac{dN}{dE} \, dE$$

where dN/dE denotes the number of individuals who were exposed to an effective dose between E and $E + dE$.

Adopting a conservative value of the effective dose for a scan to be 0.1 μSv, then the screening of 200 mil passengers will result in approximately one additional person who may develop cancer sometime in his/her life because of this one-time radiation exposure. Actually, the risk for an individual will be only 5.10^{-9} (or five per a billion), which is an extremely low value, compared with other risks encountered in our everyday life. This risk is the same as the risk corresponding to the exposure received from about 1-2 min on board a transatlantic or other flight at an altitude of about 10 km. Or, to put it in an even more demonstrable form, the same risk is associated with approximately 40 min of our life during which we are subjected to an equivalent natural radiation background which is anyway beyond our control.

The approach for deciding whether to allow whole-body scanners has to be the same as in case of mass screening for detecting TBC or breast cancer. It is justified only when we identify and cure more detected cancer cases than would be induced by the exposure of large number of examined persons. Here, the crucial element for such a decision is the degree of terrorist threat which can be reduced or eliminated by the use of rtg scanners.

5. Conclusion

The health risk resulting from the use of current sophisticated rtg whole-body scanners seems to be trivial, almost negligible comparing to other risks people are facing in everyday life or at work. The justification of their possible massive applications the following aspects has to be considered taking into account:

1. The exposure per person per scan in terms of the effective dose (this is known but may differ for various types of scanners and so further precise and reliable measurements are needed);
2. The stochastic biological effects resulting from such low exposure (this is well known based on the latest recommendations by the ICRP);
3. The number of total passengers who would be scanned per year (probably not all passengers would need this kind of checking);
4. An estimation of the number of potential terrorist attacks resulting in an fatal accident and the average number of persons who may lose their lives;
5. The fraction of those fatal accidents which would have been prevented by the interception of weapons or other dangerous articles or materials which were used by terrorists to commit such malevolent actions;
6. The risk of malfunction of a whole-body scanner which would cause an excessive exposure of passengers;
7. An analysis extent to which the whole-body scanner technology can be replaced by another type of scanning based on principles not associated with exposure to ionizing radiation; and

8. The probability of terrorists committing an attack on a civilian aircraft using smuggled tools/materials for its destruction.

If the above mentioned assessment results in the conclusion that the number of additional cancer cases due to the use of whole-body scanners is much lower than the number of casualties this technology can prevent, obviously the use of these scanners would be justified based on the present philosophy of radiation protection which relies on the latest scientific and epidemiological evidence with respect to biological effects of low level exposure. Such an approach is nothing new; it has been applied for years in making decisions regarding mass X-ray screening to detect TBC or breast cancer. Presumably it is of no use to discuss now the possible harmful impact of X-ray exposure since this has been solved by various expert bodies professionally. We can use their conclusions to assess the impact of the exposure in this particular case and weigh them with the benefit such technology offers in terms of improving the safety of passengers at large. Equally it seems ridiculous to consult the public about the danger of this highly sophisticated technology. Members of the public know and understand very little about the health effects and they are not able to put the relevant risks in perspective. On the other hand, however, the public may raise other issues which may also be important, including objections with respect to preserving the dignity and privacy of passengers. In principle, these objections may be solved technically to avoid the misuse of images showing passengers' private parts.

Acknowledgments

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