**Title: Use of Shared Warm Waiting Rooms in Nuclear Medicine: Quantitative Analysis of Staff and Patient Exposures**

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Summary:
The organization of nuclear medicine facilities, particularly those dedicated to PET, must balance quality of care and radiation protection in accordance with the ALARA principle. The evolution of PET technologies and the integration of AI improve sensitivity and allow large reductions in injected activities. In this context, the traditional practice of individual isolation room after radiopharmaceutical (RPM) injection is being questioned, since exposure levels in shared waiting rooms remain very low. This multicenter study evaluated the dosimetric consequences of using shared waiting rooms. Measurements carried out in three French departments show that the additional dose to patients is negligible (<1%) and that the increase in daily dose to technologists remains low (≈ 2.3 µSv/day), well below regulatory thresholds. No degradation in the diagnostic quality of images was observed. The use of shared waiting rooms therefore appears to comply with French regulations (ASN Guide No. 32) and provides a significant organizational benefit, enabling better patient flow management without compromising radiation protection or quality of care. The results of this study could be taken into account by the ICRP in the context of the planned revision of the radiation protection system by 2030.

Keywords: Radiological protection, waiting room, PET, ICRP, ALARA

Résumé :
L'organisation des services de médecine nucléaire, notamment ceux dédiés à la TEP, doit concilier qualité des soins et radioprotection selon le principe ALARA. L'évolution des technologies TEP et l'intégration de l'IA améliorent la sensibilité et permettent de réduire drastiquement les activités injectées. Dans ce contexte, la pratique traditionnelle d'isolation individuelle après injection de radiopharmaceutique (RPM) est remise en question, car les niveaux d'exposition en salle d'attente commune demeurent très faibles. Cette étude multicentrique a évalué les conséquences dosimétriques de l'utilisation de salles d'attente partagées. Les mesures effectuées dans trois services français montrent que la dose supplémentaire pour les patients est négligeable (<1 %) et que l'augmentation de la dose

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quotidienne pour les techniciens reste faible (≈ 2,5 µSv/jour), largement en dessous des seuils réglementaires. Aucune altération de la qualité diagnostique des images n'a été constatée. L'utilisation de salles d'attente communes apparaît ainsi conforme à la réglementation française (guide ASN n° 32) et offre un gain organisationnel significatif, favorisant une meilleure gestion des flux sans compromettre la radioprotection ni la qualité des soins. Les résultats de cette étude pourraient être pris en compte par la CIPR dans le cadre de la révision prévue du système de radioprotection d'ici 2030.

Mots Clefs : Radioprotection, salle d'attente, TEP, CIPR, ALARA

## Introduction

The organization of nuclear medicine services, particularly those dedicated to positron emission tomography (PET), must prioritize radiation protection in accordance with the ALARA (As Low As Reasonably Achievable) principle, while ensuring the quality of patient care. Recent PET technology has benefited from silicon-based detectors, improving sensitivity and diagnostic accuracy (Del Guerra et al., 2011), and the integration of artificial intelligence (AI) has further improved image quality and reduced injected activities and acquisition times (Wang et al., 2024; Zhou et al., 2020). The demand and indications for 18FDG-PET imaging have steadily increased worldwide since its introduction, and the expansion of available radiopharmaceuticals (RPM) further increases the need for PET imaging (Mason et al., 2021; Trotter et al., 2023).

Alongside, therapeutic nuclear medicine—including peptide receptor radionuclide therapy (PRRT) and theragnostics—presents new challenges and opportunities, leading departments to re-examine their organizational designs under evolving regulatory frameworks. Managing compliance with French nuclear medicine regulations and PRRT integration requires revisiting patient flows, especially as PET-related diagnostics are increasing. Given space limitations, clarity around the need for individual waiting boxes in PET practice is essential for architects, physicists, and clinicians.

The practice of isolation after RPM injection, initiated in the 1990s in the first PET-equipped departments in France (SHFJ – CEA Orsay, HIA Val de Grâce and APHP Tenon), responded to both logistical and medical reasons. Originally, PET installations were adapted to existing spaces, and strict rest protocols were introduced to mitigate stress-induced brown fat uptake, considered at this time as muscle uptake (Hany et al., 2002). This practice, soon reinforced by radiation protection concerns, spread without critical evaluation and was later supported by the American Association of Physicists in Medicine (AAPM) and the International Atomic Energy Agency (IAEA) guidelines (Atomenergie-Organisation, 2008; Madsen et al., 2006). In France nevertheless, the Nuclear Safety Authority (ASN – Autorité de Sûreté Nucléaire) Decision No. 2014-DC-0463 (ASN, 2014) and the ASN Guide No. 32 (ASN, 2020) do not mandate individual boxes for PET patient resting. Thus, the use of individual boxes has so far been based more on medical and technical considerations than on radiation protection constraints; however, if these individual boxes are to be abandoned, it is necessary to consider possible consequences for the radiation protection of staff and patients.

Nowadays, with high sensitivity PET scanners and improved understanding of brown fat uptake, the necessity of patient isolation is questionable. Several studies demonstrated in the

past that radiation doses in shared waiting areas remain extremely low, well under safety limits (Benatar et al., 2000; Harding et al., 1994; Harding et al, 1990; Madsen et al., 2006). These scientific advances encourage a reconsideration of current isolation practices for PET patients.

On the initiative of the Radioprotection working group (WG) of the French Society of Nuclear Medicine (SFMN), including members of the French Society of Medical Physics (SFPM), the French Society of Radiopharmacy (SoFra), and the French Association of Nuclear Medicine Technologists (AFTMN), a multicenter study was undertaken in order to assess the practical and regulatory aspects of patient and worker radioprotection, RPM handling, and quality of care.

In this article we present the results of this study on the radiological protection impact of using shared waiting rooms in PET imaging and their compliance with French regulations.

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## Materials and Methods

### Materials

The WG developed a common data collection methodology for all participants, primarily addressing the issue of radiation protection for patients and staff caring for patients.

The call for participation was communicated by the various learned societies involved in the WG to all volunteer departments, with no constraints on the number of machines installed, patient flow, or the size of the facilities used. It was also possible to use the usual warm waiting room (which usually accommodates patients undergoing conventional scintigraphy) to participate in this study.

Measurements were taken using the measurement devices available at each site: radiameters (APVL AT1121, APVL AT1123) and operational dosimetry systems (APVL EPD MK3 and MPI), up to date with their regulatory inspections (According to current French regulations: Decree of October 23, 2020, and Article R. 4451-48 of the French Labor Code)

### Methods

We distinguish between standard waiting days (REF), during which PET patients are installed and injected in individual boxes, and shared waiting days (COM). During shared waiting days (COM), patient injections were performed in a dedicated injection room (PET box or injection room), and patients were then invited to join the shared waiting room for their rest before the examination, with instructions not to move around too much or talk to each other. The shared waiting room could be dedicated to PET patients (only patients undergoing a PET exam) or shared with patients undergoing scintigraphic examinations (planar or SPECT nuclear medicine imaging).

Data collection per site was as follows:

1. A free text describing the patient pathway, department organization, types and number of imaging equipment, injected activities, etc.;
2. The layout of the waiting room involved in the study: configuration, area, number of seats;
3. The schedule for the day studied, specifying:
    - Opening (first injection) and closing (last patient exit) times;
    - The number and type of examinations performed during the day (cardiac SPECT, non-cardiac SPECT, PET);
4. Patient weights and injected activities for each patient in MBq and isotope (in practice, Tc99m or F18);
5. Arrival and departure times of PET patients in the waiting room;
6. Dose rate dosimetry (µSv/h) measured at 2 or 3 points in the room, recorded every hour, noting the number and type of patients present at each measurement;
7. Cumulative dosimetry in these rooms over the working day at 2 or 3 measurement points (center of the room, entrance, and back), indicating the number of patients present in the room (PET and scintigraphy);
8. Cumulative daily dosimetry for each staff member during their working day;
9. Ambient temperature in the waiting room and in the boxes;
10. Subjective feedback from the PET physician(s) on duty for COM days regarding any variations in image quality (brown fat, muscle uptake, laryngeal uptake, etc.).

To estimate the dose received by patients due to exposure from other patients, two approaches were considered. The first (Davg) used the average of ambient measurements taken while the patient was present in the waiting room. The second (Dmax) used the maximum ambient measurement value to maximize the estimated dose received from other patients. The estimated dose received from RPM was computed from the International Commission on Radiological Protection (ICRP) Publication 106 coefficients (ICRP, 2008).

**Data Analysis**

All collected data were analyzed descriptively. For patients, this analysis was performed by calculating the mean and standard deviation (of the average doses Davg and maximum doses Dmax, see above) received from other patients. For staff, data were described using median values and values received during COM and REF days, given the smaller number of measurements obtained.

Statistical comparison of dosimetric data between REF days and COM days across different sites was performed with MedCalc (Medcalc 13.1, Medcalc Software bvba), using the Mann-Whitney test (comparison of REF and COM days) or Kruskal-Wallis test (inter-site comparison).

Perplexity AI was used as a tool to assist with translation and editorial optimization. “Perplexity AI is an artificial intelligence-powered research assistant that delivers clear, accurate, and source-verified answers to support academic writing and research efficiency."

## Results

Three nuclear medicine departments participated in the measurement campaign: (1) the IMF nuclear medicine department at Saint Denis Hospital; (2) the nuclear medicine department at Perpignan Hospital; and (3) the nuclear medicine department at GCS Becquerel-Monod hospital (GCS-CHB-GHH) in Le Havre. Site 1 used a waiting room shared with scintigraphy, while sites 2 and 3 dedicated a room for shared PET waiting.

The three participating sites represented the diversity of activity, as the structures were private (IMF), public (CH Perpignan), and non-profit private (GCS-CHB-GHH). Descriptions of the three sites are provided in Table 1.

**Table 1: Description of Participating Sites' Activity**

| | Site | | |
|---|---|---|---|
| | IMF | CH Perpignan | GCS CHB-GHH |
| Number of PET device | 1 | 2 | 1 |
| Suppliers and models | GE (Omni Legend) | GE (Disco MI) + Siemens (V450) | Siemens (V450) |
| Number of technologists/PET | 2 | 3 | 3 |
| Automatic injector or dose dispenser | Injector (Lemer) | Injector (Thema) | Dispenser (Trasis) |
| Opening hours | 9am-7pm | 8am-5:30pm | 8am-5pm |
| Number of PET exams/day/device | 22 | 22 | 20 |
| Injected activity | 2 MBq/kg | Between 2 and 3 MBq/kg (according to patient habitus) | 2.5 MBq/kg |
| Dedicated PET or mixed waiting room | Mixed (PET + SPECT) | Dedicated PET | Dedicated PET |

### Patient Dosimetry

The estimation of doses received by patients was performed based on measurements for 139 patients (see Table 2).

The excess dose Davg varies by a factor of 3 between sites, from 3.2 ± 1.1 µSv (GCS CHB-GHH) to 12.2 ± 5.7 µSv (CH Perpignan) considering the average estimate. It ranges from 4.6 ± 1.7 µSv to 17.8 ± 8.7 µSv respectively, considering the most penalizing ambient measurement (Dmax). This excess dose is to be compared to the dose received by the patient due to self-exposure: 3380 ± 1137 µSv on average across the three sites.

Considering all three sites, the additional dose (Dmax) delivered to patients is 0.4% (12.5 µSv vs. 3880 µSv).

**Table 2: Patient Dosimetry**

| | Site | | | |
|---|---|---|---|---|
| | IMF (1) | CH Perpignan (2) | GCS CHB-GHH (3) | (1)+(2)+(3) |
| Number of patients included | 39 | 54 | 46 | 139 |
| Average injected activity (MBq) | 155,2 | 182,9 | 191,8 | 177,9 |
| Standard deviation (MBq) | 45,4 | 74,7 | 44,7 | 59,8 |
| Estimated dose received from RPM (µSv) | 2948,1 | 3474,5 | 3644,8 | 3380,1 |
| Associated standard deviation (µSv) | 863,3 | 1419,9 | 850,2 | 1136,8 |
| Average estimate (Davg) of dose received from other patients (µSv) | 9,1 | 12,2 | 3,2 | 8,3 |
| Associated standard deviation (µSv) | 4,8 | 5,7 | 1,1 | 5,8 |
| Maximum estimate (Dmax) of dose received from other patients (µSv) | 14,8 | 17,8 | 4,6 | 12.5 |
| Associated standard deviation (µSv) | 6,8 | 8,7 | 1,7 | 8.7 |
| Excess dose received (max estimate - %) | 0,54% | 0,53% | 0,13% | 0,40% |
| Associated standard deviation (%) | 0,34% | 0,29% | 0,06% | 0,32% |

**Technologist Dosimetry**

The comparison of doses received by technologists is shown in Table 3. The doses received by technologists are highly dependent on local practices (use of an injector, accompanying patients before and after examination, number of patients treated daily) but the differences are not statistically significant (Kruskal-Wallis: $p > 0.05$ for REF or COM days considered independently).

There is an increase in doses per patient received between REF and COM days, regardless of the site, with median increases ranging from +5.3% to +27.6%. In median daily value, this represents a maximum excess of +3.5 µSv/day at constant activity.

In multivariate analysis (with Bonferroni correction), the difference between REF and COM days appears significant ($p = 0.012$). However, this increase is only significant for site 3 (Mann-Whitney test, $p=0.004$) but not for sites 1 ($p=0.47$) or 2 ($p=0.17$) analyzed independently. The increase in daily dose remains limited and dependent on local practices and the rooms used for shared waiting.

**Table 3: Technologist Dosimetry**

| Median values | | Site IMF (1) | CH Perpignan (2) | GCS CHB-GHH (3) | (1)+(2)+(3) |
|---|---|---|---|---|---|
| Number of measurements | | 8 | 18 | 36 | 62 |
| REF days | Dose (µSv/jour) | 12.4 | 8.1 | 9.0 | 8,6 |
| | Nb of patients/technologist | 7.75 | 6 | 6 | 6 |
| | Dose/patient (µSv/patient) | 1.58 | 1.29 | 1.63 | 1.43 |
| COM days | Dose (µSv/jour) | 17.4 | 8.4 | 12,5 | 13.0 |
| | Nb of patients/technologist | 10.5 | 6 | 6 | 6 |
| | Dose/patient (µSv/patient) | 1.67 | 1.41 | 2.08 | 1.86 |
| Daily dose excess at constant activity (µSv/jour) | | 3.7 | 0.3 | 3.5 | 2.3 |
| Dose/patient excess (COM-REF)/REF | | +5.3% | +9.6% | +27,6% | +30% |
| Significance (Mann-Whitney : p) | | 0.47 | 0.17 | 0.0004 | 0.012* |

*ANCOVA test with Bonferroni correction. The normality was first confirmed with a Kolmogorov-Smirnov test.

### Diagnostic Image Quality

In the absence of obvious muscle uptake artifacts or other interpretation issues, no loss of quality or interpretation problems were reported by nuclear medicine physicians. Therefore, no quantitative study was ultimately conducted regarding the quality of diagnostic images.

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## Discussion

Nuclear medicine has transformed enormously over the last 20 years, evolving from a niche specialty to a key discipline in oncology with faster PET systems and a growing variety of RPM. Facilities are now saturated, mainly due to structural limitations, restricting patient numbers and increasing waiting times for essential examinations. A proposed solution is to modify established practices, specifically by using shared waiting rooms for PET patients as in conventional scintigraphy. While this is regulatory allowed, its actual impact, especially on patient and staff radiation exposure, needs to be studied. Patient dose increase appears negligible (~1%), but technologists' dose rise is more significant, yet still largely below regulatory limits. These results support the idea of changing practices to allow for the treatment of a larger number of patients.

Although all nuclear medicine sectors (private, public, non-profit) were invited, only three sites representing these types of practices participated. Participation was limited by the need for a dedicated PET waiting room alongside individual boxes, problematic due to common space constraints. This point proves problematic due to the space constraints already experienced in the majority of nuclear medicine departments. Additionally, the complexity of conducting measurements limited the number of test days per center.

**Radiation Protection for Patients and Companions**

Several long-standing published studies have precisely evaluated the radiation doses to which injected patients are exposed when sharing the same space. The results confirm that these exposures remain low and well below regulatory thresholds for the public.

As early as 1990, Harding et al., measured, under experimental conditions similar to ours, the radiation doses received by companions and other patients in a nuclear medicine waiting room (Harding et al., 1990). At the time, injected activities were significantly higher than today, and the radionuclides used were Tc99m, Tl201, In111, and I131. Median doses were 2.3 µSv for nurses, 2.0 µSv for relatives, and 0.2 µSv for other patients, all well below the annual recommended limits for the public. The exposure of accompanying persons was explained by the distance from the patient being accompanied and the time spent in the waiting room, which is, in median, longer than that of patients.

In 1994, a European multicenter study coordinated by the European Association of Nuclear Medicine (EANM) WG on risk management in nuclear medicine addressed the same topic (Harding et al., 1994). The median radiation dose received in the waiting room by accompanying persons was 13 µSv,. The difference with the doses indicated in the previous study (Harding et al., 1990) probably stems from different calculation assumptions. Here, the doses were estimated after normalizing the injected activity to 600 MBq and for a time spent in the room of 180 minutes. The authors concluded at the time that, given the low doses involved for patients, healthcare personnel or accompanying relatives, there was no need to consider a dedicated waiting room dedicated to injected patients and that a shared waiting room, cold or warm, was sufficient.

In a study published in 2000 (Benatar et al., 2000), focusing on the dosimetric impact for PET activity, the authors indicated that companions in the waiting room at 0.5 m from a patient could receive up to 0.1 mSv in one hour (for an injected dose of 200 MBq), which argued for the creation of dedicated warm waiting rooms for patients and cold waiting rooms outside the department for companions. The higher values compared to the previous study can be explained by the radiopharmaceuticals considered (Tc99m for SPECT vs. F18 for PET).

In 2011, Lemoine et al. (Lemoine et al., 2011) measured radiation levels emitted by patients after nuclear medicine examinations, including SPECT and PET activities. The doses measured in contact with patients did not exceed 20 µSv/h, and the potential exposure of the surroundings remained well below the annual limit of 1 mSv for the public.

In 2015, Fayad et al. showed that, at a distance of 1 meter and 3 hours after injection, dose rates were generally below 10 µSv/h, suggesting negligible cumulative irradiation for patients, healthcare personnel, and companions, remaining well below regulatory thresholds (Fayad et al., 2015).

Our study is consistent with the 2 more recent papers. The excess irradiation caused by grouping patients in a single shared waiting room (whether dedicated solely to PET activity or mixing PET and SPECT patients in the same waiting room) is less than 15 µSv/hour spent in this shared waiting room. The excess dose is clearly dependent on the geometry of the waiting room. Indeed, the area dedicated to the waiting room at site 3 was much larger (20 m² for 5 armchairs) than at site 2 (10 m² for 4 armchairs), resulting in an average maximum excess dose of around 5±2 µSv and 18±9 µSv for sites 3 and 2, respectively. As for site 1, the room

also accommodated patients undergoing scintigraphy (30 m² for 16 armchairs), hence an estimated maximum excess dose of 15±7 µSv.

These few additional µSv should be put into perspective and compared to the effective doses received by these same patients due to their examination. For example: 2700 µSv for FDG PET (70 kg, 2 MBq/kg) and 9000 µSv for a myocardial perfusion scintigraphy using technetium tracers and two passes under the camera in stress/rest protocol; the additional dose in the waiting room is less than 1% of the total irradiation.

**Radiation Protection for Professionals**

Regarding the radiation protection of staff, available data indicate that most of the exposure occurs during the administration of RPM and the positioning of patients in the examination room. For this reason, it is imperative that RPM injection be performed in a dedicated room that accommodates only one patient at a time in order to limit staff exposure. The use of shared waiting rooms should therefore only marginally impact the doses received by technologists and nuclear medicine physicians. In our study, however, based on a small sample of measurements, the excess daily dose received at constant activity (same number of patients treated) by technologists was, in median value, 2.28 µSv/day, with a wide disparity ranging from +3.71 µSv/day for site 1 to +0.33 µSv/day for site 2.

In 2000, Benatar et al. integrated specific measurements for PET activity and the consequences for staff and waiting rooms (Benatar et al., 2000). According to their measurements, technologists received an average of 14 µSv per day. No technologist exceeded 60 µSv per day, the limit in the UK. The authors concluded that PET practice did not fundamentally change the dosimetry of technologists.

In 2004, a French study on radiation protection constraints and the layout of a PET unit consisted of a specific study of tasks related to PET activity concerning staff irradiation (Balny et al., 2004). In this study, even before specific radiation protection measures dedicated to PET were implemented, the daily exposure measured for PET for a technician (using radiation protection measures) was 13 µSv per day. However, in anticipation of the development of PET-related activities, and in accordance with the ALARA principle, the authors recommended a drastic strengthening of radiation protection measures for workers, including radiation protection measures adapted to fluorine-18, such as dedicated shielded enclosures, lead screens, syringe shields, and adapted transport cases. Finally, they suggested an appropriate layout of the premises to minimize movements and optimize the RPM circuit. In this context, they proposed creating individual boxes dedicated to PET patients (3 boxes located near the hot lab and the camera), and it was in this context that they proposed adding lead to the walls of individual boxes to reduce staff irradiation.

Since this study (Balny et al., 2004), PET practice has developed considerably, and the radiation protection equipment used routinely in a PET unit has modernized and become more widespread. The use of automatic injectors has largely contributed to the reduction of occupational exposure for paramedics. At the same time, the sensitivity of the machines' detection capabilities has made it possible to reduce the activity injected into patients by at least half, if not more. The latest generation PET cameras, using AI tools to assist in patient placement and handling, result in a reduction in the time spent in contact with patients.

Even considering the heterogeneous nature of the measurements taken regarding worker irradiation from one site to another, from one day to another depending on the total number of patients, working hours, and the number of patients treated, etc., the results of our study show that, despite an observed increase in doses received with the shared waiting room configuration, daily occupational irradiation ranges, depending on the sites and measurement days, between 4 and 20 µSv/technologist/day. These values, which remain very low, should be put into perspective and compared to the mean equivalent legally-admissible dose of 27 µSv/day for category B and 90 µSv/day for category A (based on the Maximum Annual Legally-Permissible Dose of 6 mSv/year and 20 mSv/year for Category B ans A respectively), or even to natural irradiation in France, which ranges between 5 and 14 µSv/day (2-5 mSv/year depending on the region).

The increase in doses received is difficult to explain by the change in room configuration, since the exposure of technologists occurs mainly during the injection phase (in an independent box) and positioning under the camera, but more likely by a lack of optimization of practices with this new organization (immediate post-injection deperfusion without technique optimization, systematic accompaniment of patients to the waiting room). The time the technician spends on the doorstep of the common waiting room when going to get a patient could also explain a part of the dose increase.

**Quality of Care and Organizational Benefits**

From an organizational and practical standpoint, shared warm waiting rooms offer numerous advantages. They streamline patient flow and centralize their monitoring. This pooling also facilitates the work of paramedical staff, who have better visibility of all injected patients.

Feedback from the various departments that participated in the study highlights that technologists perceive this organization as facilitating their work and improving care coordination.

The quality of PET images obtained during shared waiting room days versus individual boxes was strictly identical. There were no more or fewer muscle or brown fat uptakes. However, patients should be asked not to talk to each other (to prevent functional uptake of the laryngeal muscles) and to generally remain warm, calm, and seated in their place (without walking around the department except to go to the toilet or to the water fountain in the waiting room). Since staff often have the opportunity to go to the entrance of the warm waiting room to call patients, it is easy for them to regularly remind patients of these instructions.

It appears from these experiments that even in departments organizing themselves with one or more shared warm waiting rooms, it will be useful to retain one or two individual waiting boxes. These can be used for pediatric patients, certain neurology patients, or those requiring a companion. Finally, for bedridden patients on stretchers, a dedicated space for injected bedridden patients should be provided; this space can also be shared by PET and SPECT patients, as is currently the case in many departments.

**Compliance with the international and the French Regulatory Framework**

The ALARA principle, whose origins trace back to the International Commission on Radiological Protection (ICRP) recommendations in 1954, emphasizes minimizing radiation exposure for patients and staff in PET imaging, with its formal recognition established in the

ICRP publication 26 (1977). In practice, this translates into practical measures such as the use of individual waiting rooms after the radiotracer injection, which limits the dispersion of radiation in common areas. Although these structural and procedural changes increase safety, they also reduce the number of patients that can be accommodated at once, restrict workflow flexibility, and may lengthen appointment times. The need to balance optimal radiation protection with operational capacity remains a fundamental challenge in applying ALARA in PET imaging.

Regarding the French regulation, ASN Guide No. 32, in its updated version of 10/02/2020, appears to be fully compatible with the existence of shared warm waiting rooms (ASN, 2020)). Indeed, this guide on radiation protection in nuclear medicine specifies that the organization of spaces must be based on an updated risk assessment, founded on measurement data and an analysis of actual working conditions. Scientific publications and available measurements demonstrate that shared waiting rooms can perfectly fit within this framework, provided that appropriate procedures are implemented: area demarcation, limitation of the number of patients according to injected activity and room volume, and professional training.

Article 3 of the ASN guide concerning the layout of an in vivo nuclear medicine department specifies in point No. 7 that it must include "one or more rooms dedicated exclusively to the waiting of patients to whom radionuclides have been administered" (commonly referred to as a "hot waiting room").

Article 10, dedicated to the waiting room for patients to whom radionuclides have been administered, specifies that it must be located away from circulation areas, be adapted to the number of patients treated, with separate spaces for the waiting of adults and children.

It is also indicated that the number of waiting rooms is adapted to the number of patients treated and the needs of the activity. Boxes for the rest or lying down of injected patients undergoing a PET examination are given as examples without specifying whether this is a radiation protection measure, a simple usage measure, or whether this arrangement is for medical reasons unrelated to radiation protection (e.g., brain FDG-PET examinations that require patient isolation with sensory rest before administration but without any link to radiation protection).

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## Conclusion

All available data support the use of shared warm waiting rooms in nuclear medicine departments, including for PET examinations. This organization, which necessarily requires that RPM injections be performed in a dedicated room that accommodates only one patient at a time, does not entail any significant additional radiological risk for patients or professionals and offers tangible benefits in terms of logistics and quality of care. It is part of a modernization process of departments, in compliance with the requirements of ASN Guide 32, and could constitute a relevant organizational evolution to be generalized in French nuclear medicine departments. The results of this study could be taken into account by the ICRP in the context of the planned revision of the radiation protection system by 2030 (Laurier et Schneider, 2025).

**Conflicts of interest:**

The authors declare that they have no conflicts of interest.

**Financial disclosure:**

Nothing to disclose

**Informed consent statement**

All patients included in this study were informed of the procedure and gave their informed consent.

**Ethical approval**

The study was approved by the members of the SFMN Radiation Protection Working Group, which includes the following scientific societies: SFMN, SFPM, SoFra, and AFTMN.

**Data availability:**

Data are available upon reasonable request from the corresponding author.

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**Author contributions:**

GB and SH: conceptualization, data analysis, and initial drafting of the article;
LM, EG, and AMR: performing measurements and proofreading the article;
AES: data analysis and proofreading the article;
NPB and FC: conceptualization and proofreading the article.

**References**


ASN. 2014. Décision n°2014-DC-0463 de l'Autorité de sûreté nucléaire du 23 octobre 2014 relative aux règles techniques minimales de conception, d'exploitation et de maintenance auxquelles doivent répondre les installations de médecine nucléaire in vivo. http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000030152521&dateTexte=&categorieLien=id

ASN. 2020. Guide de l'ASN n°32 : Installations de médecine nucléaire in vivo : règles techniques minimales de conception, d'exploitation et de maintenance. https://reglementation-controle.asnr.fr/content/download/111417/pdf_file/Guide%20de%20l%27ASN%20n%C2%B032.pdf

Atomenergie-Organisation, I. 2008. Radiation protection in newer medical imaging techniques: PET/CT. IAEA *Safety Reports Series* N°*58*, 41.

Balny, F., Bouhier, I., Alberini, J. L., Petegnief, Y., & Poignant, S. 2004. Contraintes de radioprotection et d'aménagement d'une unité de tomographie par émission de positons (TEP). *Innovation & Technology in Biology & Medicine*, *25*(3), 185–190. https://doi.org/10.1016/J.RBMRET.2004.03.005

Benatar, N. A., Cronin, B. F., & O'Doherty, M. J. 2000. Radiation dose rates from patients undergoing PET: Implications for technologists and waiting areas. *European Journal of Nuclear Medicine*, *27*(5), 583–589. https://link.springer.com/article/10.1007/s002590050546

Del Guerra, A., Belcari, N., Giuseppina Bisogni, M., Corsi, F., Foresta, M., Guerra, P., Marcatili, S., Santos, A., & Sportelli, G. 2011. Silicon Photomultipliers (SiPM) as novel photodetectors for PET. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *648*(SUPPL. 1), S232–S235. https://doi.org/10.1016/J.NIMA.2010.11.128

Fayad, E., Maia, S., Zilnus, A., Secchi, V., Erra, B., Perault, C., Bakhsh, A., Casset-Senon, D., Santiago-Ribeiro, M. J., & Venel, Y. 2015. Continuité des soins chez les patients en post-scintigraphie et exposition du personnel à la radioactivité. *Médecine Nucléaire*, *39*(4), 380–385. https://doi.org/10.1016/J.MEDNUC.2015.05.003

Hany, T. F., Gharehpapagh, E., Kamel, E. M., Buck, A., Himms-Hagen, J., & Von Schulthess, G. K. 2002. Brown adipose tissue: a factor to consider in symmetrical tracer uptake in the neck and upper chest region. *European Journal of Nuclear Medicine and Molecular Imaging*, *29*(10), 1393–1398. https://doi.org/10.1007/S00259-002-0902-6

Harding, L. K., Harding, N. J., Warren, H., Mills, A., & Thomson, W. H. 1990. The radiation dose to accompanying nurses, relatives and other patients in a nuclear medicine department waiting room. *Nuclear Medicine Communications*, *11*(1), 17–22. https://doi.org/10.1097/00006231-199001000-00004

Harding, L. K., Bossuyt, A., Pellet, S., Reiners, C., & Talbot, J. 1994. Radiation doses to those accompanying nuclear medicine department patients: a waiting room survey. *European Journal of Nuclear Medicine*, *21*(11), 1223–1226. https://doi.org/10.1007/BF00182357

ICRP, 2008. Radiation Dose to Patients from Radiopharmaceuticals - Addendum 3 to ICRP Publication 53. ICRP Publication 106. Ann. ICRP 38 (1-2).

Laurier D. and Schneider T. 2025. Workshop on the future of radiological protection. Radioprotection 60(1), 4–8

Lemoine, J., Bourre, J. C., & Giraud, J. Y. 2011. Dosimétrie environnementale des patients à la suite de leur examen d'imagerie médicale. *Radioprotection*. *46*(4), 533-545. https://doi.org/10.1051/radiopro/2011143

Madsen, M. T., Anderson, J. A., Halama, J. R., Kleck, J., Simpkin, D. J., Votaw, J. R., Wendt, R. E., Williams, L. E., & Yester, M. V. 2006. AAPM Task Group 108: PET and PET/CT Shielding Requirements. *Medical Physics*, *33*(1), 4–15. https://doi.org/10.1118/1.2135911

Mason, C., Gimblet, G. R., Lapi, S. E., & Lewis, J. S. 2021. Novel Tracers and Radionuclides in PET Imaging. *Radiologic Clinics of North America*, *59*(5), 887. https://doi.org/10.1016/J.RCL.2021.05.012

Trotter, J., Pantel, A. R., Teo, B. K. K., Escorcia, F. E., Li, T., Pryma, D. A., & Taunk, N. K. 2023. Positron Emission Tomography (PET)/Computed Tomography (CT) Imaging in Radiation Therapy Treatment Planning: A Review of PET Imaging Tracers and Methods to Incorporate PET/CT. *Advances in Radiation Oncology*, *8*(5). https://doi.org/10.1016/J.ADRO.2023.101212/ASSET/EAD84CAA-D51D-4515-A9C6-26ACE805D083/MAIN.ASSETS/GR2.JPG

Wang, Y., Luo, Y., Zu, C., Zhan, B., Jiao, Z., Wu, X., Zhou, J., Shen, D., & Zhou, L. 2024. 3D multi-modality Transformer-GAN for high-quality PET reconstruction. *Medical Image Analysis*, *91*, 102983. https://doi.org/10.1016/J.MEDIA.2023.102983

Zhou, L., Schaefferkoetter, J. D., Tham, I. W. K., Huang, G., & Yan, J. 2020. Supervised learning with cyclegan for low-dose FDG PET image denoising. *Medical Image Analysis*, *65*, 101770. https://doi.org/10.1016/J.MEDIA.2020.101770