



Nuclear Medicine Tools

Website

Author

Andrew Chacon andrew.chacon@austin.org.au

Contact

March 18, 2025

bb.

Contents

0.1 Project aims	2
1 Methods	3
1.1 Flow Rate Calculator	5
1.2 Physics Constants	6
1.3 Unit Conversion	7
1.4 Waste	9
1.5 BMI Calculator	11
1.6 Decay Calculator	12
1.7 Activity	15
1.8 Glomerular Filtration Rate (GFR)	16
1.9 Volume Draw Calculator	22
1.10 Physics tools - Patient discharge calculator	23
1.11 Physics tools - Population Radiopharmaceutical dose	26
1.12 Physics tools - Urgent Calculations - Exposure calculator	28
1.13 Physics tools - Urgent Calculations - Baby Breast Milk	32
1.14 Physics tools - Urgent Calculations - Administered Activity	34
2 References	36

0.1 | Project aims

The primary goal of this project is to create a website capable of performing common nuclear medicine calculations. The website will be developed using only HTML, JavaScript, and CSS to ensure compatibility with both older and newer systems. It will support all major operating systems (Ubuntu, macOS, iPadOS, Windows) and browsers (Chrome, Firefox, Chromium-based browsers such as Edge, and Safari)¹. Furthermore, the website will be designed for optimal usability across desktops, tablets, and mobile devices. While the website will not feature any novel calculations at the time of writing², it will serve as a comprehensive tool for consolidating key functions.

As of the writing of this report the current tools are

- Flow rate calculator.
- Common physics constants.
- Unit conversions.
- Waste label generator and database.
- BMI calculator.
- Decay calculator.
- Activity calculator.
- Glomerular Filtration Rate Test calculator and report generator.
- High Purity Germanium detector plotter and analyser.
- (restricted) Therapy patient discharge estimator.
- (restricted) Organ dose calculator.
- (restricted, urgent) Exposure calculator.
- (restricted, urgent) Baby breast milk exposure calculator.
- (restricted, urgent) Administered activity for aborted procedure.

After the report has been marked and accepted, I will also release it onto GIT (or equivalent) for other people to be able to download and use it.

It is extremely important to emphasise that this website is a tool not a medical device. It should not blindly be followed and all output should be appropriately questioned.

The novelty in this project is the open source modular website which can be used to consolidate and provide a uniform tool which can be used on any modern device without the user needing to install any software.

¹Internet Explorer is not supported, as it reached end of life on June 15, 2022. Devices running it should no longer be networked due to significant security risks. If a device cannot be updated but must run the website, Firefox can be installed to enable functionality.

²Novel calculations may be added in the future due to the website's modular structure.

1 | Methods

The following sections document the special features of the site which makes it as user friendly, adaptable and maintainable as possible followed by a description of how each web page operates.

1.0.1 | Modularity

The project is designed with a high degree of modularity, enabling users to add or remove web pages based on specific requirements. Each web page is capable of functioning independently, minimising shared resources, without relying on data from other web pages. Although this approach introduces some redundancy in the code, future iterations could consolidate such elements for improved efficiency at the cost of inter-dependencies. The website is intentionally developed using only HTML, JavaScript, and CSS to maximize compatibility across a wide range of devices.

1.0.2 | Light/Dark Modes and Colour Theming

The website leverages [pico.css \[15\]](#), a lightweight CSS framework developed by Lucas Larroche, which enables support for both light and dark modes, along with dynamic resizing of content. The design adapts automatically to the user's browser settings, changing between light and dark modes depending on their preferences. This feature is particularly beneficial in environments with controlled lighting, such as control rooms or reporting areas, where adjusting light levels can reduce eye strain. The [pico.css](#) framework also supports custom colour theming, with minor adjustments to improve usability specific to this website's requirements.

The website employs the following colour theming for its operations:

Table 1.0.1: Button colour and corresponding actions.

Button Colour	Action
Blue	Execute an action or calculation
Red	Close or delete an item
Pink	Load data from a database
Purple	Save data to a database

1.0.3 | Dynamic resizing

The web pages are capable of detecting the user's browser width and dynamically adjusting the sizes and positions of objects for optimal viewing. This functionality extends to mobile phones, tablets, and other smaller portable screens, ensuring that the application can be effectively used on mobile devices. This enhancement increases the versatility of the project by enabling its use on various mobile platforms. The following

Table 1.0.2: Width of the website according to browser size.

Browser size	Website size
< 576 px	browser width
576-768 px	510 px
768-1024 px	700 px
1024-1280 px	950 px
1280-1536 px	1200 px
> 1536 px	1450 px

1.0.4 | Security

Access to the physics tools is restricted by a password, which must be entered before the corresponding web page can be visited. This restriction is essential because the proper use and interpretation of the tools' outputs, such as dose calculations, require specialised training—typically held by nuclear medicine physicists. Providing unrestricted access could allow untrained users to interpret results incorrectly, potentially causing undue concern among staff members. Additionally, users should be aware that most of the restricted web pages are designed for worst-case scenario calculations, leading to conservative estimates of the highest possible dose, which may not represent the actual dose received. This distinction might not be clear to individuals without adequate technical expertise.

The security mechanism for these web pages is implemented via a “secure” command in the CSS, which hides the content and prompts the user for a password. If the correct password is entered, the content is displayed; otherwise, the page redirects to the home page. Upon successful authentication, a cookie with a one-hour timeout is created, allowing the user to access other restricted pages without re-entering the password.³ The restricted physics tools are not listed in the drop-down menu by default. To reveal them, the user must click on the “Physics tools” menu button, which triggers the password prompt. Users can log out by selecting the logout option under the Physics tools drop-down menu, which removes the cookie and redirects to the main menu.

The use of a password allows for a single website to be shared among various users without duplicating code, thereby reducing the complexity of deploying and maintaining multiple versions. The security implementation is intentionally designed to be semi-secure, acknowledging that a determined individual could bypass the CSS-based restrictions by manipulating the code. This trade-off was made to balance ease of maintenance and upgrades with reasonable security, especially for users who did not develop the original website.

The default physics password is “physicsonly.” When a password is entered, it is encrypted using the SHA256 algorithm [8] and compared with the stored hashed password. It is recommended that users replace the default password by editing the following line in the `js/security.js` file:

```
const passwordHASH = "569cd2f50924f69e3e845556bb21b99db68b63e10d1619ab2b2c37a20b6da3fb";
```

Users can generate a new hashed password using an online tool, such as [20], and replace the corresponding hash in the file. The cookie timeout can also be modified by adjusting the following line in `js/security.js`:

```
const timeout = 60; // minutes for the cookie logout
```

While SHA256 is not the most secure hashing algorithm, and storing the hashed password in the source file is not ideal for robust security, it provides sufficient protection to prevent casual or accidental access. This level of security is comparable to locking a door; any individual who deliberately circumvents the password protection would need to be appropriately reprimanded, as this would be akin to unauthorised access to sensitive data within a hospital network.

1.0.5 | Local Processing

All data is processed locally on the device where the web page is accessed, with the exception of database functionality.⁴ This ensures that no patient data is transferred off the device, thereby eliminating the risk of data leakage outside controlled environments. Although it is possible (though not recommended) to host a copy of the code locally on each machine, all actions remain client-side processes. Once the user navigates away from the web page, the data is lost.

1.0.6 | Database Integration

The website includes optional database functionality, which can be activated by setting the `useDatabase` flag to `true` and correctly configuring the database URLs and names in the `js/database.js` file:

³Note that if the website is run locally, this cookie feature may not function properly on Chromium-based browsers due to restrictions on local cookie generation. Firefox can be used to bypass this limitation.

⁴Database operations are handled separately on that server if integrated.

```
const useDatabase = false;

if (useDatabase === true)
{
    window.CONSTANTS = Object.freeze
    ({
        sharepointURL : "https://domain.sharepoint.com/sites/department", //where sharepoint is
        located
        GFRDB : "GFRDB", // The gfr database name on sharepoint
        WASTEDB : "wasteStoreDB", //the waste store database
    })
}
```

Currently only the waste and GFR web pages have database functionality included.

If SharePoint is not used, or if Microsoft discontinues support for lists (databases) or changes their operation, users can opt to host their own database. In such cases, the code remains unchanged except for updating the `sharepointURL` to the new database location, provided it operates with a RESTful interface. This design choice enhances modularity and allows organisations to locally host their database if they require stricter data control. Appropriate authentication must also be provided.

1.1 | Flow Rate Calculator

The flow rate calculator (see Figure 1.1.1) was developed to assist in determining the required delivery time for radio-pharmaceuticals based on a specified volume. This tool is particularly useful for therapeutic deliveries such as Lu-177-PSMA-617 [22, 2] or 131I-TLX-101 [1]. While the calculation of the administration time is relatively straightforward, in busy clinical settings, where doses may arrive immediately prior to administration, there is a heightened risk of errors when performing manual calculations. The web page mitigates this risk by automatically calculating the required delivery time, dividing the volume of the radio-pharmaceutical by the desired flow rate.

$$\text{Required time (min)} = \frac{\text{Volume (mL)}}{\text{Required flow rate (mL/min)}} \quad (1.1.1)$$

Home Calculators Waste Tech Tools Physics Tools

Flow Rate Calculator

The purpose of this page is to calculate infusion time required to achieve a dose rate during tracer or radiotherapy admission.

I have mL of radiopharmaceutical.

I want a flow rate of mL / min of radiopharmaceutical.

Calculate

The delivery time is Undetermined .

© Andrew Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

Figure 1.1.1: The flow rate calculator web page.

1.2 | Physics Constants

The physics constants web page provides quick access to useful physics constants in SI units, relevant for various calculations in medical physics.

- The F-18 patient-attenuated gamma constant of $0.092 \mu\text{Sv} \cdot \text{m}^2/\text{hr} \cdot \text{MBq}$ is provided by AAPM Report No. 108 [17]. This constant is highly useful in PET facilities for calculating exposure, shielding requirements, and other estimates involving F-18 and patients.
- The Tc-99m patient-attenuated gamma constant of $0.0149 \mu\text{Sv} \cdot \text{m}^2/\text{hr} \cdot \text{MBq}$ is reported by Johnson et al. [14]. Given that Tc-99m is the most commonly used radioisotope in nuclear medicine imaging, this gamma constant is crucial for similar applications.

Additionally, the Radionuclide Information booklet [7] is embedded in the web page (see Figure 1.2.1b).

By clicking on the link, users can open the PDF directly in their browser for easy navigation. This resource provides comprehensive radiation protection information for 73 commonly used isotopes in industry and medicine. It includes data on decay schemes, shielding with various materials, external dose, skin dose, internal dose coefficients, as well as methods for isotope identification and detection. Having access to this resource, which uses modern dose coefficients, facilitates timely and accurate shielding and exposure estimates.

At the bottom of the web page, a drop-down list allows users to select from 1,100 isotopes. For each selected isotope, the exposure constant, half-value layer of lead, and tenth-value layer of lead are displayed. The data is sourced from Smith and Stabin's publication [19] and has been converted into SI units for greater usability.

The figure consists of two screenshots. On the left, a screenshot of a web page titled 'Exposure Constants' under 'Patient attenuated gamma constants'. It shows a dropdown menu set to 'F-18', and four input fields: 'Exposure constant $\mu\text{Sv.m}^2/\text{hr}/\text{MBq}$ ' (0.153513514), 'HVL (mm Pb)' (4.95), 'TVL (mm Pb)' (15.1), and a note that the constants have been converted to SI units. On the right, a screenshot of the 'Canadian Radionuclide Information booklet' PDF. The title page features the Canadian Nuclear Safety Commission logo and the text 'Radionuclide Information Booklet' and 'Nover 2023'. The PDF viewer interface shows the first page of the booklet.

(a) Physics constants web page

(b) Radionuclide information booklet

Figure 1.2.1: Physics Constants web page

1.3 | Unit Conversion

There are two predominant systems of measurement used globally: SI units and empirical units. This variation can complicate calculations involving activities, doses, and exposures, particularly when the conversion is not a straightforward base-10 shift, such as converting from μCi to MBq . The challenge is further compounded by the fact that different departments may use different units. For example, chemists often express radioactivity in milliCuries, while physicists use megaBecquerels.

The web page (see Figure 1.3.1) resolves this issue by converting stored user data into the corresponding base SI units: Bq for activity, Gy for absorbed dose, Sv for equivalent dose, and C/kg for exposure. The data is then converted into the units requested by the user. The web page supports conversions for the following quantities:

- Activity
- Absorbed dose
- Equivalent dose
- Exposure

[Home](#) [Calculators](#) [Waste](#) [Tech Tools](#) [Physics Tools](#)

Unit Conversion

The purpose of this page is to convert units from SI units to imperial units, but you can also calculate SI to SI and imperial to imperial

Activity

^ v	MBq	=		mCi	v
--------	-----	---	--	-----	---

Absorbed Dose

^ v	Gy	=		Gy	v
--------	----	---	--	----	---

Equivalent Dose

^ v	Sv	=		Sv	v
--------	----	---	--	----	---

Exposure

^ v	c/kg	=		c/kg	v
--------	------	---	--	------	---

© Andrew Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

Figure 1.3.1: The Unit Conversion web page.

1.4 | Waste

Waste management is a crucial but often laborious process in radiation work. One challenge is ensuring that users both label radioactive waste properly and record it accurately in a logbook. This website aims to streamline the user experience by simplifying these procedures.

In Victoria where my training facility is located, radioactive waste must not be disposed of in landfills, and the criteria for what constitutes radioactive waste are regulated by the Victorian Radiation Regulations (2017) [5]. Therefore, maintaining an organised storage facility with proper logbooks is essential for compliance with these regulations.

To use the web page, users are required to enter their name, select the isotope from a drop-down menu, record the peak surface dose, and log the date and time of storage. For convenience, a “now” button is available, which automatically sets the current date and time. After entering the necessary information, the user must click “calculate” for the estimated discharge time to be determined. A radiation label, which can be printed and affixed to the waste, is then generated. It is recommended to have a dedicated terminal connected to a printer with self-adhesive labels, making it easy for users to attach labels to waste items.

Once labelled, users can save the record to the online database by clicking the “save to database” button. When the storage room requires maintenance, the database can be sorted by the expected release date, allowing the responsible personnel to review and release items as appropriate. The database facilitates a more organised and efficient waste management system.

If a database is utilised, the required fields for its operation are listed in Table 1.4.1.

Table 1.4.1: Fields required for database operation.

Field name	Data type	Data stored
Name	string	Name of the person storing the item
Isotope	string	Radioisotope of the waste
StoredDateTime	date with time	Date and time the object was stored
ExpReleaseDate	date	Expected release date
PeakSurfaceRate	number	Peak surface dose rate of the item
hasBeenReleased	bool (yes/no)	Indicates whether the item has been removed from storage

[Home](#) [Calculators](#) [Waste](#) [Tech Tools](#) [Physics Tools](#)

Waste Label Creator

The purpose of this is to calculate when the waste will fall below a 0.5 $\mu\text{Sv/hr}$ peak surface dose and print a radiation label for it.

Waste Details

Name:

Isotope:

Peak surface dose: $\mu\text{Sv/hr}$

Date and time:

The waste should be checked on Push Calculate

© Andrew Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

RADIATION WASTE DISPOSAL LABEL



DATE CLOSED 15 Aug 2024 13:20

ISOTOPE I131
10000 $\mu\text{Sv/hr}$
INITIALS Andrew Chacon

Expected Release Date
Sat Jan 04 2025



LAB6893-100

(a) Waste management web page.

(b) Example waste label.

wasteStoreDB					
<input type="checkbox"/> Name	<input type="checkbox"/> Isotope	<input type="checkbox"/> PeakSurfa...	<input type="checkbox"/> StoredDateTime	<input type="checkbox"/> ExpReleaseDate	<input type="checkbox"/> hadbeenReleased
User 1	Lu177	1,000	8/15/2024 1:40 PM	Today	
User 5	Gd68	100	8/15/2024 1:53 PM	Saturday	
User 2	Lu177	1,000	8/10/2024 1:40 PM	November 14	
User 2	Lu177	597	8/19/2024 1:40 PM	November 18	

(c) Waste database interface.

Figure 1.4.1: Waste management web page and its functionality.

1.5 | BMI Calculator

Calculating a patient's Body Mass Index (BMI) is an important factor in determining the appropriate radioactive dose for scans that utilise weight or BMI-based dosages. Additionally, in PET imaging, BMI can be used to calculate the standardised uptake value (SUV). There is no universally standardised method for calculating BMI, and various approaches—such as using standard BMI, lean BMI, or ideal BMI—can yield different results. To minimise the risk of errors associated with manual calculations, automating this process is crucial. This web page calculates the lean BMI using the James method [13] and the ideal BMI according to the Devine method [9].

To use the web page, the user must input the following data:

- BMI model (standard, lean, or ideal BMI).
- Tracer—F-18 or Ga-68.
- Gender—male or female.
- Height in centimeters.
- Weight in kilograms.

The user can select the desired calculation method: either standard BMI (Equation (1.5.1)), lean body mass BMI, or ideal body mass BMI. The lean body mass BMI is calculated by first determining the lean body mass (Equation (1.5.3)) using the James method, while the ideal body mass BMI is calculated using the Devine method (Equation (1.5.2)), and then applying the standard BMI equation (Equation (1.5.1)).

$$\text{BMI} = \frac{\text{Patient weight (kg)}}{(\text{Patient height (m)})^2} \quad (1.5.1)$$

Equation 1.5.1: Standard BMI calculation.

$$\begin{aligned} \text{Lean body weight}_{\text{male}} &= 1.10 * \text{weight (kg)} - 128 * \left(\frac{\text{weight (kg)}}{\text{height (cm)}} \right)^2 \\ \text{Lean body weight}_{\text{female}} &= 1.07 * \text{weight (kg)} - 148 * \left(\frac{\text{weight (kg)}}{\text{height (cm)}} \right)^2 \end{aligned} \quad (1.5.2)$$

Equation 1.5.2: Lean body weight as defined by the James method [13].

$$\begin{aligned} \text{Ideal body weight}_{\text{male}} &= 50 * 2.3 * \left(\frac{\text{height (cm)}}{2.64} - 60 \right)^2 \\ \text{Ideal body weight}_{\text{female}} &= 45.5 * 2.3 * \left(\frac{\text{height (cm)}}{2.64} - 60 \right)^2 \end{aligned} \quad (1.5.3)$$

Equation 1.5.3: Ideal body mass as defined by the Devine method [9].

The web page will also calculate the recommended standard dose and scan time based on the patient's BMI, according to the guidelines used at our training facility. The recommendations for F-18 FDG and Ga-68 tracers are as follows:

- 220 MBq with a scan time of 2 minutes per position if $\text{BMI} \leq 22$.
- 270 MBq with a bed time of 2 minutes per position if $\text{BMI} > 22$ and $\text{BMI} \leq 28$.
- 270 MBq with a scan time of 3 minutes per position if $\text{BMI} > 28$ and the patient weight is less than 77 kg.
- 3.5 MBq/kg with a maximum dose of 330 MBq if the patient weight is ≥ 77 kg.

For Gallium-68 based imaging

- 111 - 129.5 MBq with a scan time of 2 minutes per position if $\text{BMI} \leq 25$.

- 148 - 166.5 MBq with a bed time of 2.5 minutes per position if $BMI > 25$ and $BMI \leq 27$.
- 185 MBq with a scan time of 3 minutes per position if $BMI > 27$

After inputting the necessary information, the user should click “calculate,” and the patient’s BMI, dose (MBq), and scan time (min/bed) will be displayed. In the current version, the calculated data is only displayed on the web page. However, future versions may include functionality to save BMI calculations to a database, similar to the waste management web page.

1.6 | Decay Calculator

The decay calculator web page allows users to calculate the decayed or undecayed activity of an isotope. To use the web page, the following information must be entered:

- The isotope.
- Activity (the units do not affect the calculation, as both the decayed and undecayed activities will have the same units).
- Calibration time (dd/mm/yyyy hh:mm am/pm).
- Injection time (dd/mm/yyyy hh:mm am/pm).

Once the data is entered, the decayed and undecayed activities at the specified times will be calculated and displayed. Additionally, the current decayed and undecayed activities, based on the current time, will also be computed and shown.

The decayed activity is calculated using the following formula:

$$A(t) = A(0) * 2^{-\left(\frac{t}{t_{half}}\right)} \quad (1.6.1)$$

where $A(t)$ is the activity at the requested time, $A(0)$ is the initial activity, t is the time elapsed between the calibration time and the requested time, and t_{half} is the half-life of the specified isotope. The half-life is stored internally in minutes.

The undecayed activity is calculated using a similar equation:

$$A(t) = A(0) * 2^{\left(\frac{t}{t_{half}}\right)} \quad (1.6.2)$$

This equation is the same as the decay equation, but with the negative sign removed from the exponent.

The half-lives of the isotopes are stored in the `halfLifeInMins` function within the `decay.js` file.



Home Calculators Waste Tech Tools Physics Tools

Decay Calculator

This webpage will calculate the activity of isotopes which have decayed or undecayed. Undecayed means if you have this activity now, was the activity at that time.

Isotope:	<input type="text" value="F18"/>	Activity:	<input type="text"/>
Calibration Time:	<input type="text" value="dd/mm/yyyy, --:-- --"/> <input type="button" value="Calendar"/>	Injection Time:	<input type="text" value="dd/mm/yyyy, --:-- --"/> <input type="button" value="Calendar"/>
Decayed Activity:	<input type="text" value="NaN"/>	Undecayed Activity:	<input type="text" value="NaN"/>
Current Time:	<input type="text" value="16/10/2024, 10:22:39 am"/>		
Current Decayed:	<input type="text" value="NaN"/>	Current Undecayed:	<input type="text" value="NaN"/>

© Andrew Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

Figure 1.6.1: The Decay web page.

```
function halfLifeInMins(val)
{
    switch(val)
    {
        case "O15" : return 122.24 / 60;
        case "N13" : return 9.965;
        case "C11" : return 20.39;
        case "Ga68" : return 67.3;
        case "F18" : return 109.8;
        case "Tc99m" : return 6.01 * 60;
        case "Cu64" : return 12.7 * 60;
        case "I123" : return 13.27 * 60;
        case "Y90" : return 64.0 * 60;
        case "In111" : return 67.3176 * 60;
        case "Tl201" : return 72.9120 * 60;
        case "Ga67" : return 78.3 * 60;
        case "Zr89" : return 78.4 * 60;
        case "I124" : return 4.2 * 24 * 60;
        case "I131" : return 8.0207 * 24 * 60;
        case "I125" : return 59.4080 * 24 * 60;
        case "Ge68" : return 270.95 * 24 * 60;
        case "Na22" : return 951.00 * 24 * 60;
        case "Lu177" : return 6.6 * 24 * 60;

        default : return 0;
    }
}
```

To add new isotopes, the selection list in the Decay.html file must be updated to allow for the selection and assignment of the new isotope.

```
<select type="text" id="isotope" value="F18" onChange="onCalculateDecay()">
<option value="F18" selected>F18</option>
<option value="C11">C11</option>
<option value="Cu64">Cu64</option>

<option value="Ga67">Ga67</option>
<option value="Ga68">Ga68</option>
<option value="Ge68">Ge68</option>

<option value="I123">I123</option>
<option value="I124">I124</option>
<option value="I125">I125</option>
<option value="I131">I131</option>
<option value="In111">In111</option>

<option value="Lu177">Lu177</option>

<option value="N13">N13</option>
<option value="Na22">Na22</option>
<option value="O15">O15</option>
<option value="Tc99m">Tc99m</option>
<option value="Tl201">Tl201</option>

<option value="Y90">Y90</option>
<option value="Zr89">Zr89</option>

</select>
```



Activity

This webpage will calculate the activity of isotopes which have decayed or undecayed.

Isotope:

F18

Half Life (min):

109.8

Injection Time (hh:mm am/pm):

--:-- --

Initial Activity (MBq)

Initial Time (hh:mm am/
pm)

--:-- --

Residual Activity (MBq)

Residual Time (hh:mm
am/pm)

--:-- --

Administered Activity

Administered Activity (MBq):

Activity at administered time (MBq):

Residual at administered time (MBq):

© Andrew Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

Figure 1.7.1: The Activity web page.

1.7 | Activity

The purpose of the activity web page is to calculate the amount of radioactivity (dose) administered to a patient. To use this web page, the user must input the following information:

- Isotope.
- Injection time (hh:mm am/pm).
- Initial activity (MBq) — this is the activity measured when the dose was drawn up.
- Initial time (hh:mm am/pm).
- Residual activity (MBq).
- Residual time (hh:mm am/pm).

The web page then calculates and displays the administered activity after accounting for the residual activity. It also displays the activity in the syringe at the time of administration, along with the residual activity corrected to the administration time.

The administered activity is calculated using the following equation:

$$A_{\text{administered}} = A_{\text{initial}} * 2^{-\left(\frac{t_1}{t_{\text{half}}}\right)} - A_{\text{residual}} * 2^{\left(\frac{t_2}{t_{\text{half}}}\right)} \quad (1.7.1)$$

where:

- $A_{\text{administered}}$ is the activity administered at the time of injection.
- A_{initial} is the initial activity, decay-corrected for the time t_1 (the time between the initial measurement and the injection).
- A_{residual} is the residual activity, (un)decay-corrected for the time t_2 (the time between the residual measurement and the injection).

1.8 | Glomerular Filtration Rate (GFR)

The Glomerular Filtration Rate (GFR) test is a nuclear medicine procedure designed to measure kidney function. The test involves injecting the patient with a radiopharmaceutical, performing a blood pool planar scan, and subsequently taking blood samples at three time points, typically one-hour intervals, to measure the amount of radiopharmaceutical remaining in the blood. The GFR calculation follows the procedure outlined by Flemming et al. [11].

A summarised method for calculating GFR is as follows: Each blood sample is background-corrected using the average background and average activity of the sample. A plot of counts vs. time is generated, and an exponential equation is fitted using a least-squares method. From this, the Y-intercept at time zero (T_0) is calculated, along with the plasma half-life based on the fitted equation. The plasma volume and distribution volume are calculated as:

$$\text{Plasma volume} = \frac{\text{Reference counts}}{\text{T}_0 \text{ plasma counts}} \times \frac{\text{Dose (MBq)}}{\text{Reference activity}} \times \text{Dilution factor} \quad (1.8.1)$$

The GFR is then calculated using the following equation:

$$\text{GFR (mL/min)} = \text{Plasma volume at } T_0 \times \frac{\ln(2)}{\text{Plasma half-life}} \quad (1.8.2)$$

The Dubois method is used to calculate the body surface area (BSA) using the equation:

$$\text{BSA (m}^2\text{)} = 0.007184 \times \text{Height (cm)}^{0.725} \times \text{Weight (kg)}^{0.425} \quad (1.8.3)$$

The BSA-corrected GFR is calculated as:

$$\text{GFR}_{\text{m}^2} = \frac{\text{GFR}}{\text{BSA}} \quad (1.8.4)$$

To normalise for a standard body surface area of 1.73 m^2 , the following equation is used:

$$\text{GFR}_{1.73\text{m}^2} = \frac{\text{GFR}}{\text{BSA}} \times 1.73 \quad (1.8.5)$$

The Brochner-Mortensen correction is applied to the GFR as follows:

$$\text{GFR}_{\text{BM corrected}} = 0.991778 \times \text{GFR} - 0.001218 \times \text{GFR}^2 \quad (1.8.6)$$

To use the GFR web page, the user must input the following information:

- **User Information:** The name of the technologist, physician, or person performing the test.
- **Patient Details:**

- URN (unique patient identifier).
- First name.
- Last name.
- Gender.
- Date of birth.
- Height (cm).

- Weight (kg).

■ Calibration:

- Background water counts (initial and repeat measurements).
- Standard measurement counts (initial and repeat measurements).

■ Patient Administration Details:

- Injection time (hh:mm am/pm).
- Dilution volume (mL).
- Patient pre-activity (MBq).
- Patient post-activity (MBq).
- Standard pre-activity (MBq).
- Standard post-activity (MBq).

■ Sample Measurements:

- Time and counts for Sample 1 (with repeat measurement).
- Time and counts for Sample 2 (with repeat measurement).
- Time and counts for Sample 3 (with repeat measurement).

If the database functionality is enabled, users can load previously saved patient data by clicking the pink button, which prompts the user to enter the patient's URN. If a matching URN is found, a drop-down list will appear, displaying available dates for the patient's records.

The web page is designed to prevent overwriting of patient data, ensuring the integrity of the database. Only administrators can delete patient records, which can be done via the back-end by selecting and deleting the desired record. If a data-saving error occurs, an authorised administrator can resolve the issue by deleting the record in the back-end.

When a GFR report is generated, the system calculates both a single-time-point GFR and a triple-time-point GFR, based on the method by Flemming et al. [10]. Although the single-time-point GFR is not displayed to the user, it is stored in the database for internal comparison purposes.

The single-time-point GFR is calculated using the following code in the `gfr.js` file:



Glomerular Filtration Rate

The purpose of this tool is to calculate the glomerular filtration rate for nuclear medicine patients

[load test data \(3 time point\)](#)[load test data \(single\)](#)[Clear form](#)

User:

Test data 1

GFR Type:

 Single 3 time point

Patient Details

URN:

1234

First Name:

Test

Last Name:

Data

Gender:

 Male Female

DOB:

24/07/2024



Calibration

Background Water

Counts 1:

26

Counts 2:

41

Standard

Counts 1:

240000

Counts 2:

250000

Patient Details

Injection Time (hh:mm am/pm):

08:37 am

Dilution (mL):

500

Patient Activity

Pre (MBq):

140

Post (MBq):

10

Standard Activity

Pre (MBq):

20.8

Post (MBq):

0.9

Samples

Sample 1 Time (hh:mm am/pm):

10:37 am

Counts 1:

22000

Counts 2:

21000

Sample 2 Time (hh:mm am/pm):

11:36 am

Counts 1:

15000

Counts 2:

16000

Sample 3 Time (hh:mm am/pm):

12:16 pm

Counts 1:

13000

Counts 2:

12000

[Calculate GFR](#)

Figure 1.8.1: The GFR web page with sample data.

```
const dsv = (PatientDose / StandardDose)*Dilution;
const CPM_Admin = dsv*StdAverageBgdCor;
const halflifeCorr = Math.pow(0.5, sampleData.timemm[0] / (10000.0 * 60.0) )
const CPM_Admin_calc = StdAverageBgdCor * Dilution * PatientDose / StandardDose * halflifeCorr;
const Vapp = CPM_Admin_calc / sampleData.counts[0];
const Vapp_norm = Vapp / 1000.0 * (1.73/bsa_single);
const GFR_single =((5862.0 + 1282.0 * bsa_single + 15.5 * sampleData.timemm[0] ) *
Math.log(Vapp_norm) - (11297.0 + 4883.0 * bsa_single + 41.9 * sampleData.timemm[0] )) /
sampleData.timemm[0];
const GFR_single_BMCOR = 1.0004*GFR_single-0.00146*Math.pow(GFR_single,2);
```

After entering the necessary data, the user has the option to print the GFR report and save the results to the database. The saveToDatabase function, similar to the waste database functionality, stores all inputs, results, and single-time-point GFR calculations in the database.

GFR Report



Patient Name:	Test DATA	UR:	1234	DOB:	24 Jul 2024
---------------	-----------	-----	------	------	-------------

Samples					
	1	2	BGCor		
Water BG:	26	41	34		
Standard	240000	250000	244967	Fit	Acq Time
Plasma 1	22000	21000	21500	21444	119 mins
Plasma 2	15000	16000	15500	15507	178 mins
Plasma 3	13000	12000	12500	12447	218 mins

Syringe Activity			
	Pre (MBq)	Post (MBq)	Given (MBq)
Standard	20.8	0.9	19.9
Patient Dose	140	10	130.0

Height (cm):	160	Weight (kg):	100	Dilution (mL):	500
Plasma Count					
T ₀ :	41235 ± 331		T _{1/2} :	126 ± 1	
BSA:	2.02		EVC:	19405	19%

Average Adult GFR	
Male 125 ± 15 L/min/(1.73m ²)	

GFR				
GFR	GFR (mL/Min)	GFR/m ² (mL/Min)	GFR/1.73m ² (mL/Min)	GFR (%)
Non BM-Corrected	106.62	52.90	91.52	73.22
BM-Corrected			80.57	64.45

Date Calculated: 17 Mar 2025

Entered By: Test data 1

Figure 1.8.2: An example of a printed GFR report.

```
function saveToDataBase()
{
    var siteUrl = window.CONSTANTS.sharepointURL;

    getRequestDigest().done(function(data)
    {
        var requestDigest = data.d.GetContextWebInformation.FormDigestValue;
        var listName = window.CONSTANTS.GFRDB;
        var listItemEntityTypeFullName = "SP.Data."+listName+"ListItem";

        $.ajax({
            url: siteUrl + "/_api/web/lists/getbytitle('" + listName + "')/items",
            type: "POST",
            data: JSON.stringify({
                '__metadata': { 'type': listItemEntityTypeFullName },
                //Input
                'user': document.results.personEntered.value,
                'urn': document.results.ur.value,
                'dateentered' : document.results.dateEntered.value,
                'firstname': document.patient.fName.value,
                'lastname': document.patient.lName.value,
                'gender': document.results.gender.value,
                'dob': document.results.dob.value,
                'height': document.results.resHeight.value,
                'weight' : document.results.resWeight.value,
                'waterc1': document.results.waterBg1.value,
                'waterc2' : document.results.waterBg2.value,
                'standardc1' : document.results.std1.value,
                'standardc2': document.results.std2.value,
                'injectiontime' : document.study.iTime.value,
                'dilution' : document.results.resDilution.value,
                'prepatientactivity' : document.results.syringePtPre.value,
                'postpatientactivity' : document.results.syringePtPost.value,
                'prestandardactivity' : document.results.syringeStandardPre.value,
                'poststandardactivity' : document.results.syringeStandardPost.value,
                's1time' : document.Samples.s1Time.value,
                's1c1' : document.results.plasma1ct1.value,
                's1c2' : document.results.plasma1ct2.value,
                's2time' : document.Samples.s2Time.value,
                's2c1' : document.results.plasma2ct1.value,
                's2c2' : document.results.plasma2ct2.value,
                's3time' : document.Samples.s3Time.value,
                's3c1' : document.results.plasma3ct1.value,
                's3c2' : document.results.plasma3ct2.value,

                //The results
                'waterave' : document.results.waterBgAve.value,
                'waterstd' : document.results.stdave.value,
                'plasma1ave' : document.results.plasma1ave.value,
                'plasma1fit' : document.results.plasma1fit.value,
                'plasma1time' : document.results.plasma1time.value,
                'plasma2ave' : document.results.plasma2ave.value,
                'plasma2fit' : document.results.plasma2fit.value,
                'plasma2time' : document.results.plasma2time.value,
                'plasma3ave' : document.results.plasma3ave.value,
                'plasma3fit' : document.results.plasma3fit.value,
                'plasma3time' : document.results.plasma3time.value,
                'syringestandardgiven' : document.results.syringeStandardGiven.value,
                'syringeptgiven' : document.results.syringePtGiven.value,
                'calct0' : document.results.T0.value,
                'calct12' : document.results.T12.value,
            })
        });
    });
}
```

```

'bsa' : document.results.BSA.value,
'evc' : document.results.EVC.value,
'genavgfr' : document.results.genderValue.value,
'nonbmgr' : document.results.nonBMCorrected.value,
'nonbmgrm' : document.results.nonBMCorrected_GFRm.value,
'nonbmorgfr173m' : document.results.nonBMCorrected_GFR173m.value,
'nonbmgrperc' : document.results.nonBMCorrected_GFRperc.value,
'gfrbmcor173m' : document.results.BMCorrected_GFR173m.value,
'bmcorgrperc' : document.results.BMCorrected_GFRperc.value,

//for a single timepoint gfr
'single_bsa' : global_bsa_single,
'single_dsv' : global_dsv,
'single_CPM_Admin' : global_CPM_Admin,
'single_halflifeCorr' : global_halflifeCorr,
'single_CPM_Admin_calc' : global_CPM_Admin_calc,
'single_Vapp' : global_Vapp,
'single_Vapp_norm' : global_Vapp_norm,
'single_GFR' : global_GFR_single,
'single_GFR_BMCOR' : global_GFR_single_BMCOR,

}),
headers: {
  "Accept": "application/json;odata=verbose",
  "Content-Type": "application/json;odata=verbose",
  "X-RequestDigest": requestDigest
},
success: function (data) {
  alert("Record added successfully!");
},
error: function (error) {
  alert("Error adding record: " + JSON.stringify(error));
}
});
}).fail(function(error) {
  alert("Error retrieving request digest: " + JSON.stringify(error));
});
}

```

1.9 | Volume Draw Calculator

The purpose of this web page is to assist users in calculating the volume of stock solution to draw in order to obtain a desired activity. To use the web page, the user must enter the stock volume (in mL), the stock activity, and the desired activity. The user can select the units for the activity from the following options:

- Bq
- kBq
- MBq
- GBq
- nCi
- μ Ci
- mCi
- Ci



Volume Draw Calculator

The purpose of this page is to calculate the volume required to draw up from a solution to achieve a desired activity.

I have mL of stock radiopharmaceutical. The stock activity is: GBq

I want MBq of radiopharmaceutical.

Calculate

The draw volume is:

Figure 1.9.1: The Volume Draw Calculator web page.

Once the data is entered, the user clicks the "calculate" button, and the required volume to draw is displayed. The calculation is performed using the following equation:

$$\text{Required volume draw} = \text{Stock volume} / \text{stock activity} * \text{desired activity} \quad (1.9.1)$$

Internally, all activity values are converted and stored in Bq for consistent calculations. .

1.10 | Physics tools - Patient discharge calculator

The purpose of this web page is to assist in determining when a patient may be safely discharged from a department following radio-nuclide therapy. The ARPANSA RPS 4 guidelines for the discharge of patients treated with radioactive substances recommend discharge limits of $25 \mu\text{Sv}/\text{hr}$ measured at 1 meter, $9 \mu\text{Sv}/\text{hr}$ at 2 meters, or $5 \mu\text{Sv}/\text{hr}$ at 1 meter [3].

It is important to emphasise that this web page provides only a guide for discharge based on external dose rates. A patient may meet the discharge criteria but still require hospitalisation if they pose additional risks, such as vomiting or having a long public transport journey home (> 2 hours). The final decision regarding discharge from a radiation safety perspective should be made by a nuclear medicine physicist or qualified personnel, and access to this web page is therefore restricted by password.

The web page provides two discharge time estimates:

1. Based on population-average discharge rates.
2. Based on individual patient-specific clearance rates.

To estimate discharge times, the following inputs must be provided:

- Measurement distance — 1, 2, or 3 meters.
- (Optional) Radiopharmaceutical used — currently, options are Na-I-131 and Lu-177-PSMA.
- (Optional) Estimated effective half-life (hours). Default values are 15.4 hours for Na-131 and 2 hours⁵ For Lu-177-PSMA these values are based on observations made over several months at my training facility using PSMA-617.

⁵This is not the effective half-life but the early clearance half-life, which is more useful for estimating discharge times.

- Measurement time (dd/mm/yyyy hh:mm am/pm) and dose rate ($\mu\text{Sv}/\text{hr}$).
- (Optional) For individual clearance estimates, additional patient-specific measurements of dose rate at different times should be entered.

The patient-specific effective half-life is obtained by fitting an exponential decay function to the dose rate data to determine the decay constant.

The estimated discharge time is calculated using the following equation:

$$\text{Elapsed time} = \frac{\log\left(\frac{A_{\text{lim}}}{A_0}\right)}{\lambda} \quad (1.10.1)$$

where the elapsed time is the time required for the patient's dose rate to decrease to the discharge limit. This time is added to the initial measurement time to calculate the estimated discharge time. A_{lim} is the selected external exposure discharge limit ($\mu\text{Sv}/\text{hr}$), A_0 is the dose rate measured at the initial time point and specified distance, and λ is the decay constant, calculated as $\lambda = \frac{\log 2}{t_{\text{half}}}$, where t_{half} is the effective half-life.

The population-based discharge time is calculated using the same equation, but with predefined half-lives.

The default population half-lives can be modified or additional radiopharmaceuticals can be added by updating the `externalDose/externalDose.js` file:

```
function updateBiologicalHalfLife()
{
    var selection = document.getElementById("radiopharmaceuticalSelect").value;
    if ( selection === 'Undetermined' )
    {
        document.getElementById('popHalfLife').value = 0;
    }
    else if ( selection === 'NaI131' )
    {
        document.getElementById('popHalfLife').value = 15.4;
    }
    else if ( selection === 'Lu177PSMA' )
    {
        document.getElementById('popHalfLife').value = 2;
    }
}
```

Additionally, the `discharge.html` file should be modified to update the drop-down selection:

```
<select type="text" id="radiopharmaceuticalSelect" value="Undetermined"
    onchange="updateBiologicalHalfLife()">
    <option value="Undetermined"> Undetermined </option>
    <option value="NaI131"> Na-I131 (thyroid) </option>
    <option value="Lu177PSMA"> Lu177-PSMA </option>
</select>
```

[Home](#) [Calculators](#) [Waste](#) [Tech Tools](#) [Physics Tools](#)

Exposure Discharge Calculator

This webpage will estimate when a patient can be discharged after radiotherapy. There are two calculations performed, one based on the patient observed data and one based on population average data. Discharge limits are as Per the Victorian regulations as of July 2024.

Optional parameters:

Distance measurement:
1 meter (limit: 25 $\mu\text{Sv/hr}$)

Radiopharmaceutical:
Undetermined

With an estimated effective half-life (h) of:
15.4

Patient specific measurements:

Measurement 1:	Dose Rate ($\mu\text{Sv/hr}$)	Comment
dd/mm/yyyy, ----	300	
New entry	Clear previous entry	Clear all entries

Measurement 2:	Dose Rate ($\mu\text{Sv/hr}$)	Comment
17/10/2024, 09:00 am	150	
New entry	Clear previous entry	Clear all entries

[Calculate fit](#)

Predicted discharge time based on patient measurements
Undetermined with an effective clearance half-life (h) of Undetermined

Population discharge time (based on population effective half-life)
Undetermined

Predicted discharge time based on patient measurements Sat 19 Oct 0456 with an effective clearance half-life (h) of 17

Population discharge time (based on population effective half-life) Fri 18 Oct 2312

[Print Page](#)

(a) The patient discharge web page.



(b) Patient discharge calculator with example calculation.

(c) Patient discharge printed report.

Figure 1.10.1: Patient discharge calculator and its functionality.

1.11 | Physics tools - Population Radiopharmaceutical dose

The purpose of this web page is to provide an easy way to calculate radiopharmaceutical doses based on population data. The organ dose information is derived from ICRP 128 [18]. To use the web page, the user should select the administered radiopharmaceutical and input the dosage, either in MBq or mCi. Upon clicking “calculate,” the organ doses and effective doses will be computed for the following age groups: adults, 15-year-olds, 10-year-olds, 5-year-olds, and 1-year-olds. This tool is particularly useful for evaluating how changes in administered doses affect organ and effective doses, and for preparing medical physics reports for clinical trials.

It is important to emphasise that this tool provides average doses across populations and should not be used to calculate individual patient doses. Significant variability can exist between patients, especially in cases where biological clearance times differ from the average.

To add additional radiopharmaceuticals or modify existing organ dose data, the ICRP organ dose tables must be converted into JavaScript arrays and added to the `radiopharmaceuticalDose` directory. The new data file should be listed in the import section of the `radiopharmaceuticalDose.js` file, as shown below:

```
//Importing all of the data
let jsFiles = [
  'FDG.js',
  'Tc99mMIBIRest.js',
  'Tc99mMIBIExercise.js',
  'Tc99mMDP.js',
  'Tc99mPertechnetate.js',
  'Tc99mMAA.js',
  'Tc99mMAG3.js'
];
```

Additionally, the radiopharmaceutical should be added to the switch statement in the same file to ensure proper dose calculation, with the appropriate row headers chosen for each radiopharmaceutical:

```
switch(radiotracer)
{
  case "F18 FDG": organDoseData = FDG; rowHeadersToDisplay = rowHeadersNoSavGlands; break;
  case "Tc99m MIBI Rest": organDoseData = Tc99mMIBIRest; break;
  case "Tc99m MIBI Exercise": organDoseData = Tc99mMIBIExercise; break;
  case "Tc99m MDP": organDoseData = Tc99mMDP; rowHeadersToDisplay = rowHeadersNoSavGlands;
    break;
  case "Tc99m Pertechnetate": organDoseData = Tc99mPertechnetate; break;
  case "Tc99m MAA": organDoseData = Tc99mMAA; rowHeadersToDisplay = rowHeadersNoSavGlands;
    break;
  case "Tc99m MAG3": organDoseData = Tc99mMAG3; rowHeadersToDisplay = rowHeadersMAG3; break;
}
```

Finally, in the `radiopharmaceuticalDose.html` file, the radiopharmaceutical must be added to the drop-down list for user selection:

```
<select id="radiopharmaceutical" onChange="clearTable()">
<option value="F18 FDG"> F18 FDG </option>
<option value="Tc99m MIBI Rest"> Tc99m MIBI Rest </option>
<option value="Tc99m MIBI Exercise"> Tc99m MIBI Exercise </option>
<option value="Tc99m MDP"> Tc99m MDP </option>
<option value="Tc99m Pertechnetate"> Tc99m Pertechnetate </option>
<option value="Tc99m MAA"> Tc99m MAA </option>
<option value="Tc99m MAG3"> Tc99m MAG3 </option>
</select>
```



Population radiopharmaceutical dose

The purpose of this webpage is to get a quick population estimation of the organ dose and whole body effective dose from radiopharmaceuticals. All data is taken from [ICRP 128, ICRP, 2015, Radiation Dose to Patients from Radiopharmaceuticals: A Compendium of Current Information Related to Frequently Used Substances. ICRP Publication 128, Ann. ICRP 44\(2S\)](#).

F18 FDG	270	MBq			
Calculate					
F18 FDG Organ Dose (mGy)					
	Adult	15 Year old	10 Year old	5 year old	1 year old
Adrenals	3.24	4.32	6.48	10.53	19.17
Bone surfaces	2.97	3.78	5.94	9.18	17.28
Brain	10.26	10.53	11.07	12.42	17.01
Breast	2.38	2.97	4.86	7.83	15.12
Gallbladder wall	3.51	4.32	6.48	9.99	18.90
Stomach wall	2.97	3.78	5.94	9.45	18.09
Small intestine wall	3.24	4.32	6.75	10.80	19.71
Colon wall	3.51	4.32	6.75	10.53	18.90
Upper large intestine wall	3.24	4.05	6.48	10.26	18.90
Lower large intestine wall	3.78	4.59	7.29	11.07	18.90
Heart wall	18.09	23.49	35.10	56.70	102.60
Kidneys	4.59	5.67	7.83	12.15	21.06
Liver	5.67	7.56	11.34	17.01	32.40
Lungs	5.40	7.83	11.07	16.74	32.40
Muscles	2.70	3.51	5.40	8.91	16.74
Oesophagus	3.24	4.05	5.94	9.45	17.82
Ovaries	3.78	4.86	7.29	11.61	20.52
Pancreas	3.51	4.32	7.02	10.80	20.52
Red marrow	2.97	3.78	5.67	8.64	15.93
Skin	2.11	2.59	4.05	7.02	13.50
Spleen	2.97	3.78	5.67	9.45	17.82
Testes	2.97	3.78	6.48	9.99	17.82
Thymus	3.24	4.05	5.94	9.45	17.82
Thyroid	2.70	3.51	5.67	9.18	17.55
Urinary bladder wall	35.10	43.20	67.50	91.80	126.90
Uterus	4.86	5.94	9.72	14.58	24.30
Remaining organs	3.24	4.05	6.48	10.26	17.28
Effective dose (mSv)	5.13	6.48	9.99	15.12	25.65

© Andrew Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

Figure 1.11.1: Population Radiopharmaceutical organ dose web page.

1.12 | Physics tools - Urgent Calculations - Exposure calculator

The purpose of this web page is to provide a rapid, worst-case scenario estimate of the effective dose and radiation risk that a person may receive from a diagnostic or therapeutic nuclear medicine patient. This tool is designed for use in urgent situations where time for precise calculations is limited, such as when a nuclear medicine patient requires immediate transfer to the emergency department, self-discharges from the hospital, or is involved in an unusual travel situation. The page offers an upper bound on radiation exposure, serving as a quick check before more accurate, patient-specific dose calculations are performed. This tool can help determine whether immediate intervention is required if the estimated dose exceeds a user-defined threshold (e.g., 0.5 mSv).

The default exposure scenarios and contact frequencies are based on the work of Bartlett [6], and users can modify these settings as needed. Biological clearance rates are taken from ICRP 128 [18], and radiation risk is calculated using ICRP 103 [12].

Given the complexity of interpreting radiation risk, this web page is password-protected to prevent misuse by individuals without the necessary technical expertise. Unrestricted access could lead to unnecessary concern, especially among non-technical staff attempting to calculate their personal radiation exposure.

To use this web page, the user should input the following information:

- The gender of the exposed population or population group.
- The age of the exposed population (if gender is selected).
- The radiopharmaceutical administered to the nuclear medicine patient.
- The activity of the administered radiopharmaceutical.
- The time in hours from the end of the scan to the first exposure.

The estimated exposure at a distance of 1 meter will be displayed. If a different exposure rate is required, the user can modify the administered activity. This approach is used because, in emergencies, there may not be time to measure the patient's specific exposure rate, but the administered dose is typically known or as a worst case scenario the standard dosage can be used.

It is important to note the following:

- For the radiopharmaceuticals listed in the drop-down menu, the effective dose rate is calculated at the end of the procedure. If a scan was not completed due to patient self-discharge or other emergencies, the corresponding aborted isotope should be selected.
- Aborted procedures incorporate patient-specific attenuation factors for gamma constant calculations (see Physics Constants page).
- For aborted procedures, only physical decay is considered for exposure calculations, not biological decay.

Once the user enters the required data, they can load a recommended exposure pattern or create custom exposure events using the “New Row” button. The user can also modify default exposure frequencies based on their specific needs. Each row provides a drop-down menu to select whether the exposure is from a single event or a recurring daily event. For example, the user could specify a 6-hour exposure at 0.5 meters on day 1 (e.g., a long drive home), followed by a recurring 5-hour daily exposure at 3 meters.

All exposure events are calculated at the start of each day, ensuring a conservative dose estimate. Physical decay during an exposure event is included, while biological decay is applied only between events (including the first event if a delay is included).

The dose is calculated using the following formula:

$$\text{Dose} = \sum_{\text{day } 0}^{\text{Day } 59} \left(B(\text{day}) \cdot P(\text{day}) \cdot \sum_{\text{events}} \frac{D_{\text{ref}}}{D_x} \cdot E \cdot \frac{1 - e^{-\ln(2) \cdot t / T_{\text{phys}}}}{\ln(2) / T_{\text{phys}}} \right) \quad (1.12.1)$$

Where:

- $B(\text{day})$ is the biological decay coefficient.
- $P(\text{day})$ is the physical decay constant.
- T_{phys} is the physical half-life.
- t is the exposure duration.
- E is the exposure rate.
- D_{ref} is the reference distance (1 meter).
- D is the exposure distance.
- x is the power rule exponent.

Distances between 10 cm and 1 meter are calculated using the exposure rate at 10 cm and the 1.5 power rule, while distances between 1 and 3 meters use the 1 meter exposure rate and the 1.5 power rule. Distances beyond 3 meters are calculated similarly.

$$B = \sum_{x=1}^3 C_x \cdot 0.5^{\frac{\text{day}+T_{\text{delay}}}{T_{\text{bio},x}}} \quad (1.12.2)$$

Where:

- $T_{\text{bio},x}$ is the biological half-life for term x .
- C_x is the coefficient for biological clearance.
- T_{delay} accounts for the delay between the end of the scan and the first exposure.

The physical decay is calculated using the standard decay formula:

$$P = 0.5^{\frac{\text{day}+T_{\text{delay}}}{T_{\text{phys}}}} \quad (1.12.3)$$

The effective dose will be automatically calculated and displayed. If the dose exceeds 100 μSv , an orange warning will appear, and if the dose exceeds 1 mSv, a red warning will be shown.

Similar to the other web pages, the radiopharmaceuticals can be modified or custom radiopharmaceutical can be added by modifying the `ProcedureSelect` if statement and the `setDefault` value function in `exposure/exposure.js` to include the desired radiopharmaceutical to the selection list as shown below:

```

if (ProcedureSelect === "FDG")
{
    closeContactExposure = 214; // exposure at 10cm uSv / hr
    baselineExposure = 16; // uSv / hr at 1m
    halfLife = 109.0 / 60.0; //hours, physical half life
    activityScalar = adminActivity[0].value / 285.0; //administered activity divided by
        reference activity

    bioCoeff[0] = 0.06;
    bioCoeff[1] = 0.18;
    bioCoeff[2] = 0.76;

    bioHalfLife[0] = 0.2; // in hours
    bioHalfLife[1] = 1.5; // in hours
    bioHalfLife[2] = 9999; // in hours

}
.
.
.
```

```
function setDefaultValues()
{
.
.
.
if (ProcedureSelect === "FDG" )
adminActivity[0].value = 285.0; //in MBq
.
.
.
}
```

The new radiopharmaceutical should also be added to the HTML drop down list in the `exposure.html` file.

```
<select id="ProcedureSelect" onchange="setDefaultValues();updateWidth('ProcedureSelect')"
        class="dynamic-width">
<option value="FDG">F18 FDG</option>
.
.
.
</select>
```



[Home](#) [Calculators](#) [Waste](#) [Tech Tools](#) [Physics Tools](#)

Dose to a person from a patient who underwent a nuclear medicine procedure

This tool is designed to estimate the maximum dose from the following scenarios. This should only be used as an initial estimation by a nuclear medicine physician. This tool is designed to be used in emergency or urgent case scenarios where not much information is known about specific patient doses or exposure distances. Where possible the default values in this tool should be changed to match actual data.

The data on this webpage is based on the publication by Barlett, M.L. (2013). Estimated dose from diagnostic nuclear medicine patients to people outside the Nuclear Medicine department. In Radiation Protection Dosimetry (Vol. 157, Issue 1, pp. 44-52). Oxford University Press (OUP). <https://doi.org/10.1093/rpd/nct119>. NOTE: default doses have been modified to doses used by my training facility.

All biological data is taken from ICRP 108, ICRP, 2013. Radiation Dose to Patients from Radio pharmaceuticals: A Compendium of Current Information Related to Frequently Used Substances. ICRP Publication 108, Ann. ICRP 44(2).

Radiation risk is based on the ICRP 103 and should be considered population risk NOT an individual risk. [Use with extreme care](#). ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103, Ann. ICRP 37(2-4).

Assumptions

- All dose is calculated simultaneously at t=0 to maximise the dose. This will provide an upper limit and mean that the dose is independent of the order of exposure.
- Day 2 and onwards will follow the same exposure pattern as input, calculated for 60 days post exposure
- The delay between the first scan and the first exposure is only applied to the first day
- Biological decay will only be calculated inter event, with physical decay occurring during the exposure event only.
- This is the dose at the end of the procedure, not a procedure that has been aborted or partially completed.
- The aborted procedures are only physical decay and assume that the patient was administered dose then immediately left. They use the gamma constants with patient attenuation taken into account.

Calculation

A: Male - 50-59 years old, near a nuclear medicine patient who underwent 131I Ablation therapy with an activity of 3000 kBq. Estimated activity at 1 meter at end of procedure: 25.00 µCi/hr.

Load a recommended template

Partner, where patient is at home with them

What is the delay between the end of the scan and the first exposure (h): 0

Activity 1: Distance (meter): 0.5 Duration (hour): 8 Daily exposure

Comment: Sleeping same bed

Activity 2: Distance (meter): 1 Duration (hour): 1 Daily exposure

Comment: Near each other in house, sitting aside

Activity 3: Distance (meter): 2 Duration (hour): 4 Daily exposure

Comment: Sitting at table, same room a

Activity 4: Distance (meter): 3 Duration (hour): 4 Daily exposure

Comment: In house different room a

Activity 5: Distance (meter): 5 Duration (hour): 7 Daily exposure

Comment: In house far away ac

[New Now](#) [Clear Rows](#)

Effective dose: 329.7 µSv. **Caution: High dose warning**

The lifetime attributable risks of cancer incidence from this exposure is 24.1 Per one million

[Print this page](#)

© Andrine Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

[Home](#) [Calculators](#) [Waste](#) [Tech Tools](#) [Physics Tools](#)

Dose to a person from a patient who underwent a nuclear medicine procedure

This tool is designed to estimate the maximum dose from the following scenarios. This should only be used as an initial estimation by a nuclear medicine physician. This tool is designed to be used in emergency or urgent case scenarios where not much information is known about specific patient doses or exposure distances. Where possible the default values in this tool should be changed to match actual data.

The data on this webpage is based on the publication by Barlett, M.L. (2013). Estimated dose from diagnostic nuclear medicine patients to people outside the Nuclear Medicine department. In Radiation Protection Dosimetry (Vol. 157, Issue 1, pp. 44-52). Oxford University Press (OUP). <https://doi.org/10.1093/rpd/nct119>. NOTE: default doses have been modified to doses used by my training facility.

All biological data is taken from ICRP 108, ICRP, 2013. Radiation Dose to Patients from Radio pharmaceuticals: A Compendium of Current Information Related to Frequently Used Substances. ICRP Publication 108, Ann. ICRP 44(2).

Radiation risk is based on the ICRP 103 and should be considered population risk NOT an individual risk. [Use with extreme care](#). ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103, Ann. ICRP 37(2-4).

Assumptions

- All dose is calculated simultaneously at t=0 to maximise the dose. This will provide an upper limit and mean that the dose is independent of the order of exposure.
- Day 2 and onwards will follow the same exposure pattern as input, calculated for 60 days post exposure
- The delay between the first scan and the first exposure is only applied to the first day
- Biological decay will only be calculated inter event, with physical decay occurring during the exposure event only.
- This is the dose at the end of the procedure, not a procedure that has been aborted or partially completed.
- The aborted procedures are only physical decay and assume that the patient was administered dose then immediately left. They use the gamma constants with patient attenuation taken into account.

Calculation

A: Working Age Population - near a nuclear medicine patient who underwent Tc99m Aborted Procedure with an activity of 1000 kBq.

MtBq. Estimated activity at 1 meter at end of procedure: 23.84 µCi/hr.

Load a recommended template

None

What is the delay between the end of the scan and the first exposure (h): 0

Activity 1: Distance (meter): 0.1 Duration (hour): 3 Single exposure

Comment:

New Now Clear Rows

Effective dose: **1.9 mSv WARNING! DOSE IS > 1 mSv**

The lifetime attributable risks of cancer incidence from this exposure is 80.3 Per one million

[Print this page](#)

© Andrew Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

(a) Example of a high-dose iodine ablation patient scenario without radiation safety protocols.

(b) High-dose warning from a patient undergoing an aborted Tc-99m procedure followed by close-contact, long duration surgery.

Figure 1.12.1: Exposure calculator examples and functionality.

1.13 | Physics tools - Urgent Calculations - Baby Breast Milk

The purpose of this web page is to calculate the effective dose a baby will receive from consuming the breast milk of a mother who has undergone a nuclear medicine procedure. This web page provides a worst-case scenario calculation, estimating the upper bound of expected radiation exposure under the most extreme conditions. The baby's effective dose is calculated based on the methodology described by Leide-Svegborn et al. [16].

It is assumed that the baby feeds every 4 hours, consuming 133 mL over a 30-minute feeding session. Internal milk exposure is calculated using the exposure factors provided in the publication, while external exposure is calculated using patient-attenuated gamma constants for the isotope. These constants are decay-corrected for each feeding point. The effective dose is calculated using the following equation:

$$E = A * \text{Exposure constant} * \sum_{\text{time}=0+d}^{\text{time}=100} A * 0.5^{-\frac{T_{\text{eff}}}{\text{time}}} * Y * t \quad (1.13.1)$$

Where:

- d is the delay time after the procedure and before the first feed.
- A is the administered dose to the mother in MBq.
- *Exposure constant* is the exposure factor provided by Leide-Svegborn et al. [16].
- Y is the gamma exposure constant at 1 meter for the isotope.
- t is the baby's feeding time (0.5 hours).

In addition to calculating the effective dose, the web page displays the recommended cessation time for breastfeeding based on the ARPANSA 14.2 guidelines [4].



Home Calculators Waste Tech Tools Physics Tools

New born exposure through breast milk

This tool is to only be used by a nuclear medicine medical physicist. The calculations and output from this tool require experienced understanding and interpretation.

The purpose of this tool is to provide urgent calculations and advice on the dose to newborns. This will estimate worst case scenario doses and list the [ARPANSA RPS 14.2 \(as of July 2024\)](#) and calculated interruption periods.

This tool is designed to provide estimations of dose in an emergency or urgent case. Both the contact and milk internal dose are taken into account. New born dose can be significantly different to the listed dose depending on several patient and baby factors. **Proceed with care when using this tool**

The new born effective dose coefficients are taken from: [Leide-Svegborn, S., Ahlgren, L., Johansson, L., & Mattsson, S. \(2016\). Excretion of radionuclides in human breast milk after nuclear medicine examinations. Biokinetic and dosimetric data and recommendations on breastfeeding interruption. In European Journal of Nuclear Medicine and Molecular Imaging \(Vol. 43, Issue 5, pp. 808–821\). Springer Science and Business Media LLC. https://doi.org/10.1007/s00259-015-3286-0](#)

This tool assumes:

- The baby feeds every 133 mL every 4 hours.
- The baby feeds for 30 minutes.
- External exposure is calculated via the gamma constants of the isotope with patient attenuation factors included.

Mothers Radiotracer:

F18 FDG

Mothers administered activity (MBq):

270

Time between mothers radiotracer administration and baby's first feed (hour):

0

Calculate

Effective dose:

681 µSv

ARPANSA cessation time:

1 hour for 400 MBq

© Andrew Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

Figure 1.13.1: New born milk exposure web page with example calculation.

1.14 | Physics tools - Urgent Calculations - Administered Activity

This web page is designed to assist in determining the amount of radiopharmaceutical that was administered to a patient when the initial administration was interrupted due to technical issues or other complications, and the patient requires additional dosing to complete their scan. It is important to note that the procedures and assumptions in this web page only hold if the time between the initial and top up is short. Extended delays will mean that both doses will be at different steady states during imaging and this may impact biological modelling that is inherently applied when calculating SUVs or other parameters.

First, the amount of radioactivity already in the patient is estimated using the patient-attenuated gamma constants (see the Physics Constants page):

$$A_{\text{estimated}} = \frac{D_1}{\gamma_{\text{patient attenuated}}} \quad (1.14.1)$$

where:

- D_1 is the dose rate measured at 1 meter from the patient using an H*10 probe.
- $\gamma_{\text{patient attenuated}}$ is the gamma constant for the isotope, accounting for patient attenuation.

This provides an estimate of the baseline activity within the patient. Based on this estimate, the patient can be “topped up” to the desired activity level. After the additional radioactivity has been administered, the patient should be re-measured to determine the patient-specific gamma factor.

Once the patient has been topped up, the patient-specific gamma factor is calculated using the known radioactivity added to them:

$$\gamma_{\text{patient specific}} = \frac{D_2 - D_1 \cdot 0.5^{t_1/T_{\text{half}}}}{A_2 \cdot 0.5^{t_2/T_{\text{half}}} - A_3 \cdot 0.5^{t_3/T_{\text{half}}}} \quad (1.14.2)$$

Where:

- D_2 is the remeasured dose rate after the top-up.
- t_1 is the time between the first and second measurements.
- A_2 is the topped-up activity.
- t_2 is the time between the dose calibration and the second measurement after the top-up.
- A_3 is the residual activity in the syringe.
- t_3 is the time between the residual measurement in the syringe and the second external dose rate measurement.
- T_{half} is the physical half-life of the isotope.

Finally, the accurate amount of radiopharmaceutical in the patient at the second measurement time point can be calculated using:

$$A_{\text{total}} = \frac{D_2}{\gamma_{\text{patient specific}}} \quad (1.14.3)$$

Where:

- A_{total} is the total amount of radiopharmaceutical in the patient at the second time point.
- D_2 is the dose rate measured at the second time point.
- $\gamma_{\text{patient specific}}$ is the patient-specific gamma constant.



[Home](#) [Calculators](#) [Waste](#) [Tech Tools](#) [Physics Tools](#)

Emergency administered activity calculator

The purpose of this page is to get an emergency calculation of the activity that is administered to the patient. This is for the scenario that a patient has been partially administered an unknown activity and needs a top up activity or has been given a top up activity prior to a scan.

The radioisotope is:

Using a H*10 probe, the patient's external dose rate at 1 meter is: $\mu\text{Sv/hr}$ at

The estimated activity is MBq of radiopharmaceutical.

Patient specific gamma constant

If you top up the patient you can get a more accurate estimation of the activity by calculating the patient specific Γ constant:

The patient is topped up with MBq with a reference time of with a residual of MBq and time of

The remeasured external dose rate at 1 meter is: $\mu\text{Sv/hr}$ at

The estimated activity in the patient is MBq at

© Andrew Chacon and Graeme O'Keefe. All rights reserved. [User License Agreement](#)

Figure 1.14.1: The administered activity web page with an example calculation.

2 | References

- [1] Study details | 131I-TLX-101 for treatment of newly diagnosed glioblastoma (IPAX-2) | ClinicalTrials.gov.
- [2] Study details | EVOLUTION: 177Lu-PSMA therapy versus 177Lu-PSMA in combination with ipilimumab and nivolumab for men with mCRPC | ClinicalTrials.gov.
- [3] ARPANSA . Discharge of patients undergoing treatment with radioactive substances. 4.
- [4] ARPANSA . Radiation protection in nuclear medicine. 14.2.
- [5] State Government of Victoria . Radiation regulations 2017.
- [6] M. L. Bartlett. Estimated dose from diagnostic nuclear medicine patients to people outside the nuclear medicine department. *Radiation Protection Dosimetry*, 157(1):44–52, May 2013.
- [7] Canadian Nuclear Safety Commission. *Radionuclide information booklet*. Ottawa : Canadian Nuclear Safety Commission, 2017.
- [8] Information Technology Laboratory Computer Security Division. Hash functions | CSRC | CSRC.
- [9] Ben J Devine. Gentamicin therapy. 1974.
- [10] John S. Fleming, Linda Persaud, and Maureen A. Zivanovic. A general equation for estimating glomerular filtration rate from a single plasma sample. *Nuclear Medicine Communications*, 26(8):743–748, August 2005.
- [11] John S. Fleming, Maureen A. Zivanovic, Glen M. Blake, Maria Burniston, and Philip S. Cosgriff. Guidelines for the measurement of glomerular filtration rate using plasma sampling. *Nuclear Medicine Communications*, 25(8):759–769, August 2004.
- [12] ICRP. The 2007 recommendations of the international commission on radiological protection. ICRP publication 103. *Ann. ICRP*, 37(2-4):1–332, 2007.
- [13] W. P. T. JAMES. Research on obesity*. *Nutrition Bulletin*, 4(3):187–190, September 1977.
- [14] Thomas E Johnson and Brian K Birky. *Health physics and radiological health*. Lippincott Williams and Wilkins, Philadelphia, PA, 4 edition, December 2011.
- [15] Lucas Larroche. Minimal css framework for semantic html.
- [16] Sigrid Leide-Svegborn, Lars Ahlgren, Lennart Johansson, and Sören Mattsson. Excretion of radionuclides in human breast milk after nuclear medicine examinations. biokinetic and dosimetric data and recommendations on breastfeeding interruption. *European Journal of Nuclear Medicine and Molecular Imaging*, 43(5):808–821, January 2016.
- [17] Mark T. Madsen, Jon A. Anderson, James R. Halama, Jeff Kleck, Douglas J. Simpkin, John R. Votaw, Richard E. Wendt, Lawrence E. Williams, and Michael V. Yester. Aapm task group 108: Pet and pet/ct shielding requirements. *Medical Physics*, 33(1):4–15, December 2005.
- [18] S. Mattsson, L. Johansson, S. Leide Svegborn, J. Liniecki, D. Nofsker, K.Å. Riklund, M. Stabin, D. Taylor, W. Bolch, S. Carlsson, K. Eckerman, A. Giussani, L. Söderberg, and S. Valind. Icrp publication 128: Radiation dose to patients from radiopharmaceuticals: a compendium of current information related to frequently used substances. *Annals of the ICRP*, 44(2 suppl):7–321, June 2015.
- [19] David S. Smith and Michael G. Stabin. Exposure rate constants and lead shielding values for over 1, 100 radionuclides. *Health Physics*, 102(3):271–291, March 2012.
- [20] Fatih Telis. Sha256 encrypt/decrypt.
- [21] Sean Wilson, Dustin Osborne, Misty Long, Josh Knowland, and Darrell R. Fisher. Practical tools for patient-specific characterization and dosimetry of radiopharmaceutical extravasation. *Health Physics*, 123(5):343–347, July 2022.
- [22] Madhav Prasad Yadav, Sanjana Ballal, Ranjit Kumar Sahoo, Madhavi Tripathi, Nishikant Avinash Damle, Shamim Ahmed Shamim, Rakesh Kumar, Amlesh Seth, and Chandrasekhar Bal. Long-term outcome of 177Lu-psma-617 radioligand therapy in heavily pre-treated metastatic castration-resistant prostate cancer patients. *PLOS ONE*, 16(5):e0251375, May 2021.