How To Buy An Apron

MAVIG

Overview of Contents

How To Buy An Apron

When deciding between different radiation protective aprons, particularly if you will be wearing them for long periods of time, weight is probably one of the most important criteria.

This criteria is primarily defined by two factors, which are explained in the following chapters.

Chapter 1 The Special Cut of a Radiation Protective Apron

and

Chapter 2 Lead Equivalent and Protective Materials

Even without a detailed explanation, a short checklist can help you to decide:

The Apron Checklist

What should you look for when choosing an apron?

- ☐ Is there a CE label with the four-digit identification number of the notified body?
- ☐ Does the apron comply with the current standards IEC 61331:2014 / DIN EN 61331:2016? Important: Check for the correct year!
- ☐ Does the information about the X-ray tube voltage range (... kV) match the conditions at your workplace?
- ☐ Is the length of the protective clothing sufficient for your height (the apron should reach to the knees)?
- ☐ Are there any ways in which you can distribute the weight of the apron?
- ☐ Are the armholes suitable?
- ☐ Is the apron comfortable to move around in?

Important Criteria when Choosing an Apron

The Right Length

A very short costume skirt or a short apron / coat will of course reduce the weight of the protective clothing.

There is **hematopoietic bone marrow** located in the knee joint[1], which is why IEC 61331-3:2014 / DIN EN 61331-3:2016 state that:

§ *"Protective aprons shall be designed to cover ... down to at least the knees."* (also see fig. 1).

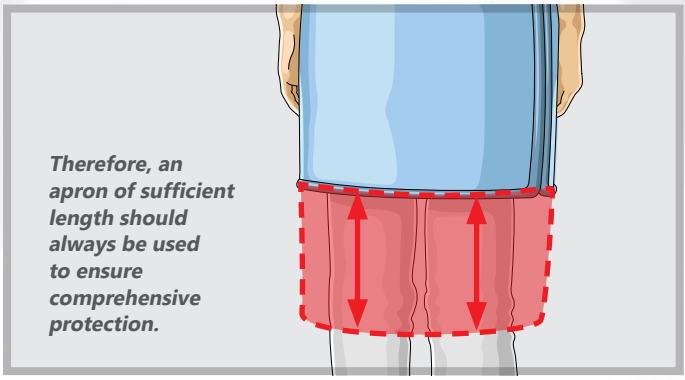


Fig. 1: Questionable weight reduction by having a skirt that only reaches to the middle of the thigh.

The Armhole

An apron that is too large will have two negative consequences: The apron is heavier than required and there may be gaps in the protected areas, e.g. caused by armholes which are too large.

Particularly with women, this can lead to breast tissue being exposed (marked in red, fig. 2 and 3). Breast tissue is classified as particularly sensitive. [2]

Armholes should follow **the ALARA principle:**
As small as possible and only as large as absolutely necessary ("ALARA" – As Low As Reasonably Achievable).

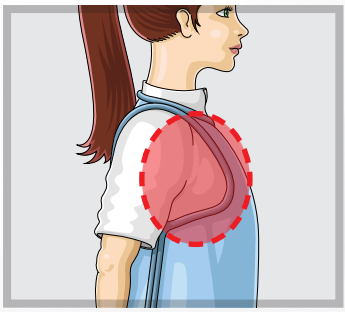


Fig. 2: Having an armhole that is too large can result in breast tissue being exposed.

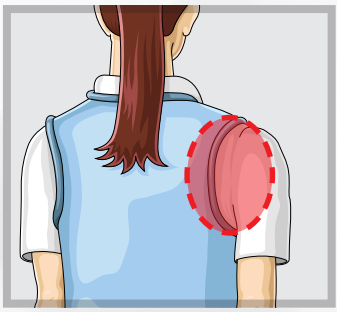


Fig. 3: An armhole which extends too far across the back does not ensure a sufficient level of protection.

[1] Cristy, M., 1981: *Active bone marrow distribution as a function of age in humans.* Physics in Medicine & Biology 2007, 26 (3), p.389.

[2] ICPR: *Recommendations of the International Commission on Radiological Protection* ICRP, 2007: Publication 103 (Users Edition). Ann. ICRP 37 (2-4)

Important Criteria when Choosing an Apron

Weight Distribution / Ergonomics

The weight of a radiation protective apron is easy to assess if you have an opportunity to try it on.

Of course, the most important thing is that you select the correct size.

While a radiation protective apron which is too small is indeed lighter, it does not guarantee adequate protection.

Therefore, when choosing a suitable radiation protective apron you should also pay special attention to weight relief systems. These systems distribute the weight of the radiation protection apron ergonomically and in doing so, significantly increases the wearing comfort for the user.

In general, there are two different systems available:

The radiation protective apron is split up into two pieces (costume) with a vest and a skirt. This way, the hips carry a significant part of the weight of the apron and relieve the shoulders. Additionally, the weight of the skirt can be borne comfortably by the hips with a wide stretch insert integrated in the back of the skirt (fig. 4).

If you are wearing an apron / one-piece coat the weight can again be distributed to the hips with a stretch belt that runs around the body (fig. 5).

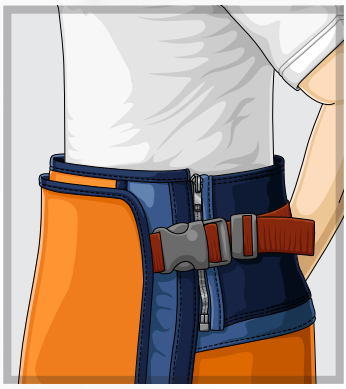


Fig. 4: Skirt with stretch insert.

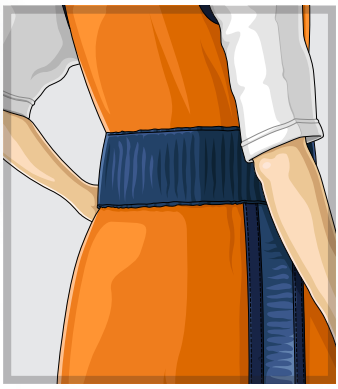


Fig. 5: Coat with stretch belt.

TIP: When closing the belt of the coat, lift your shoulders up slightly. Thus, the weight of the coat will partially rest on the hips and will not be completely borne by the shoulders.

Also when wearing front protective aprons the shoulders can be relieved from the total weight burden. Clever inclusions of stretch inserts redistribute the weight and support the back.

In order to avoid placing any additional load on the shoulders, radiation protective aprons should always be fitted with soft shoulder pads.

Important Criteria when Choosing an Apron

The Overlapping Area in the Front *(costumes and coats)*

There are two different designs:

I. Both front panels of the protective apron have the specified lead equivalent value

The only advantage of this option is that the user is always protected with at least the specified lead equivalent value after closing the apron.

Disadvantage: Due to the design, there is always an area of overlap, which has twice the lead equivalent value. Consequently, you have to carry more weight than necessary.

II. Both front panels have roughly half the lead equivalent value – overlapping ensures the specified lead equivalent value

In terms of weight, option II is better than option I. However, you need to be aware that the desired lead equivalent value is only achieved in the overlapping area.

You should specifically check with the apron manufacturer whether the shoulder parts, where the front panels a lot of times do not overlap, have the full lead equivalent value.

In addition, it may happen that the apron is not closed correctly, e.g. due to carelessness. As a result, there may be areas with only half of the specified lead equivalent value.

Fig. 6: Colour-contrasting safety zones to ensure that the vest and skirt are securely closed.

MAVIG has solved these problems with their patented "Safety Zones".

The areas on the sides and on the shoulders separated by seams in the outer material already have the full lead equivalent value.

Thus, the shoulder parts are optimally protected and the safety zone on the side makes it easy to correctly adjust the front panels, fig. 6.

In order to visually differentiate the safety zones, they are always manufactured in the colour "Ocean", regardless of the colour of the apron.

TIP: The safety zones are also an ideal help to check if the correct apron size is chosen. If the front panel ends in the safety zone, the size is right for you.

Important Criteria when Choosing an Apron

The Overlapping Area in the Back *(costumes)*

If the overlapping area between vest and skirt on the back is not sufficient, it will result in gaps in the radiation protection when bending (Fig. 7).

Therefore, for radiation protective reasons, it does not make sense to chose a particularly short vest in order to reduce the total weight of the apron.

Fig. 7: An inadequate overlap of the vest and skirt is dangerous, for example when bending over.

Does Lead-Free mean Lighter?

When it comes to radiation protection, you can decide between three different types of protective materials: leaded, lead-reduced and lead-free.

Unfortunately, many users still think that "lead-free" translates into a lighter protective material and thus, a particularly light protective apron. However, research **proves that wrong**.

The following brief overview of the different protective materials explains the relationship between material and weight:

I. **Pure lead materials:** The standard protective material for shielding against X-rays is lead. Lead is a high-Z-material, meaning an element with a high atomic number i.e. a high number of protons.

A high-Z-material such as lead is very effective at shielding the user from X-rays in the clinically relevant range of 50 – 150 kV almost irrespective of the X-ray tube voltage (see fig. 8).

So, protective materials with lead have a stable lead equivalent value from 50 – 150 kV. On the downside, a high atomic number means that the protective material has a higher weight.

II. **Lead-reduced materials:** In lead-reduced protective materials lead is mixed with other materials which have a lower atomic number than lead.

This means that the protective material is somewhat lighter (for the same surface area). However, low-Z-materials do not protect as well at low and high X-ray tube voltages. The lead equivalent value changes depending on the X-ray tube voltage (see fig. 9).

How much the lead equivalent value fluctuates depends on what other materials are used along with the lead and in what quantities. That means that in practice, radiation protective aprons with lead-reduced protective material usually only meet the specified lead equivalent within the tolerances for an X-ray tube voltage range of 50 - 110 kV. Thus, they are also only approved for this range.

III. **Lead-free materials:** In lead-free protective materials, lead is completely replaced by another material, which usually has a lower atomic number.

Depending on the material, it may be the case that the protective material is considerably lighter for the same surface area. But, as mentioned above, low-Z-materials provide lower protection against certain X-Ray tube voltages than pure lead materials. As lead is completely replaced in lead-free materials, this can cause significant changes in the lead equivalent value, depending on the X-Ray tube voltage (see fig. 10).

In this case, many times the specified lead equivalent of the protective material is only met at certain x-ray tube voltages. If a different voltage is used, the user's protection may be significantly lower than expected.

But that doesn't mean that lead-free radiation protective aprons cannot guarantee adequate protection. For example, if you completely replace lead with bismuth, you will be just as protected. On the other hand, as bismuth is directly next to lead in the periodic table, the radiation protective apron would not be lighter.

The following graphs illustrate the relationship between the different materials over the entire X-ray tube voltage range of 50 - 150 kV (measured in accordance with the current standard IEC 61331-1:2014).

In the case of the lead-free material, a material with elements with low atomic numbers is shown.

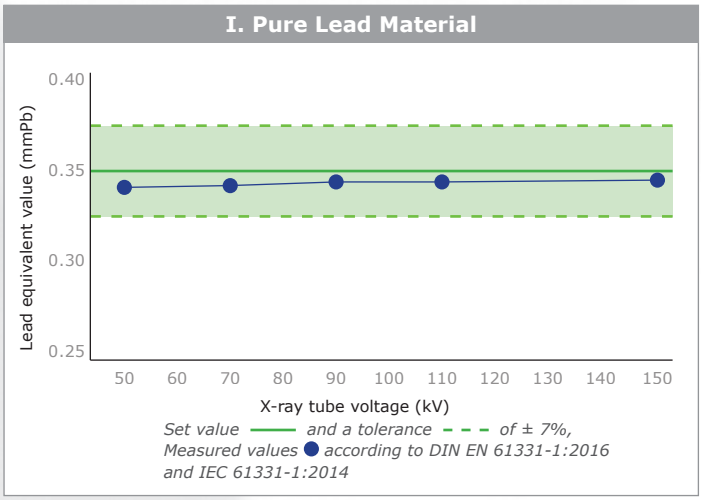


Fig. 8: Lead equivalent value of a pure lead material in the 50 - 150 kV range

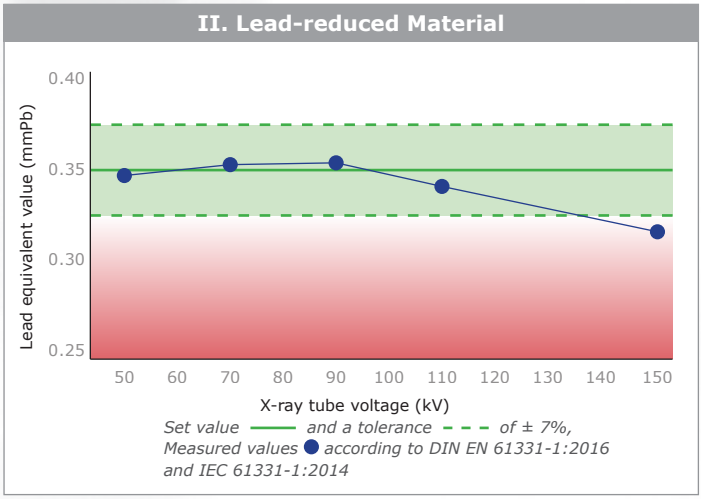


Fig. 9: Lead equivalent value of a lead-reduced material in the 50 - 150 kV range

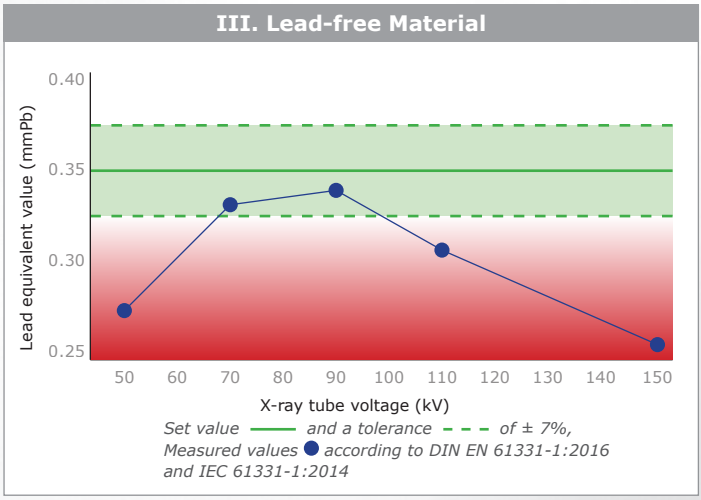


Fig. 10: Lead equivalent value of lead-free material in the 50 - 150 kV range

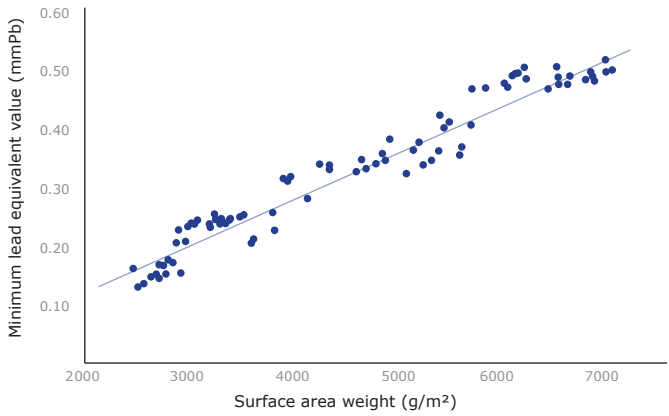
The Surface Area Weight

Generally speaking, any material can provide sufficient protection if it is configured correctly. Currently, this is only ensured through the norms IEC 61331:2014 / DIN EN 61331:2016.

In order to be adequately protected over the entire X-Ray tube voltage range, it is important that the radiation protective apron maintains a certain weight. [3]

The following graphic clearly shows this relationship.

Weight Comparison of Various Serial Protective Materials



Measured values ● minimum lead equivalent value of different serial materials from various manufacturers according to IEC 61331-1:2014, over the respective surface area weight.

Fig. 11: Minimum lead equivalent value of different serial materials from various manufacturers

Figure 11 shows the lead equivalent values of different serial materials from various manufacturers determined from 50 kV - 150 kV according to IEC 61331-1:2014. From the determined lead equivalent values, the lowest value was plotted over the surface area weight of the respective material.

It is clear that a lower surface area weight goes hand in hand with a lower lead equivalent value and therefore a lower level of protection. The same applies vice versa. A higher lead equivalent value with a correspondingly higher level of protection usually has a higher surface area weight.

[3] Lichliter A et al: Clinical Evaluation of Protective Garments with Respect to Garment Characteristics and Manufacturer Label Information. J Vasc Interv Radiol 2017, Vol. 28, pp. 148 - 155

The Right Radiation Protective Apron

The lead equivalent value required for your workplace depends on the working conditions (radiation protection present on-site, X-Ray tube voltage, position in the room, etc.) and cannot be determined generally.

In Germany, radiation protection commissioners monitor and supervise the measures taken to ensure adequate radiation protection in environments where ionizing radiation is used. If you have questions about radiation protection, this person is the first point of contact at your workplace.

Apart from that, each person that wears a radiation protective apron should be assured that he or she is properly protected with the lead equivalent value mentioned on the radiation protective clothing in the X-ray tube voltage range that they need. To that end, always make sure that the lead equivalent value of your radiation protective clothing complies with the current standard IEC 61331-1:2014 or DIN EN 61331-1:2016.

Further, you should check in which X-ray tube voltage range you work and for which range your preferred protective clothing is approved for. For example, if you only work at 80 kV - 100 kV, the lighter protective clothing made from reduced-lead / lead-free material, which is mostly tested in and approved for the 50 kV - 110 kV range, is best. On the other hand, for procedures, such as CT interventions, it is imperative that the material has been tested and approved for the entire X-ray tube voltage range from 50 kV to 150 kV. In this case, MAVIG recommends that you use pure lead or an equivalent protective material.

Why are Some Aprons Significantly Lighter than Others? – A Brief History of Measurement Methods

Today, it is still possible that some aprons are significantly lighter than others. This is due to the fact that not all manufacturers have changed their production to the latest technology (IEC 61331-1:2014 / DIN EN 61331-1:2016). Radiation protective clothing, which was approved before the introduction of the new standards, retains its CE certification for the time being, which is why it is particularly important to pay attention to the year of the norms/standards.

Why does the lead equivalent value fluctuate with a partial or complete replacement of lead? And why can some radiation protective aprons receive a CE certification despite having a suspiciously light weight?

To clarify these questions, we must take a closer look at the measurement methods used in the past and today to determine the lead equivalent value.

I. Measurement method of the preceding standards IEC 61331-1: 1994 / DIN EN 61331-1:2006

In these standards, the lead equivalent value of a protective material is determined in the narrow beam condition. However, going into the technical details of the determination of the lead equivalent value would go outside of the boundaries of this leaflet.

What is important to know: When taking the measurement, the measuring chamber is not placed directly behind the sample (the protective material) (see fig. 12).

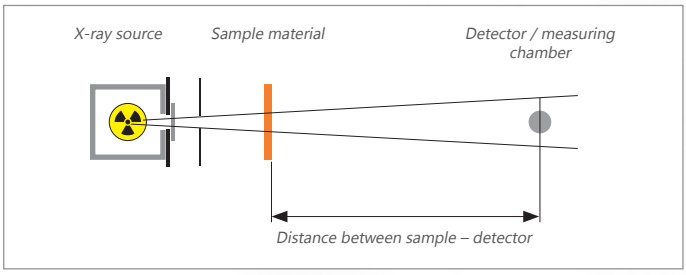


Fig. 12: Schematic representation according to the older DIN EN 61331-1:2006

II. Measurement method of the current state-of-the-art IEC 61331-1: 2014 / DIN EN 61331-1:2016

In contrast to the standards mentioned above, the lead equivalent is now determined in the inverse broad beam condition.

What is important to know: With this measurement, the measuring chamber is placed directly behind the sample (the protective material) (see fig. 13).

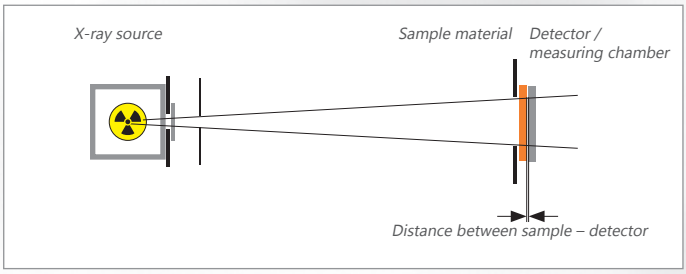


Fig. 13: Schematic representation according to the currently applicable DIN EN 61331-1:2016

As a matter of fact, measurement method II, although in a slightly modified form, has been required by the German standard DIN 6857-1:2009 since 2009. Due to the update of the standard series 61331, this norm has been withdrawn.

If we have a material that contains just lead, both measurement methods will give a similar lead equivalent value. However, if the measurement method from category I is used with lead-reduced and lead-free materials, a false result would be given and the lead equivalent value would be shown to be higher than it actually is. The reason for this are the "non-lead materials".

Certain "non-lead materials" emit a secondary radiation, so-called fluorescence radiation, when subject to typical medical X-ray tube voltages (80 kV - 100 kV). This fluorescence radiation is low-energy and only has a very small range in the air. Therefore, fluorescence radiation can only be measured directly behind the radiation protection material. [4, 5] If, like with category I, the measuring chamber and the sample are far apart, the fluorescence radiation will not be detected and therefore the lead equivalent value will be incorrectly measured as higher than its actual value. Consequently, a correct lead equivalent value for all materials can only be determined by using the category II measurment method (or the withdrawn DIN 6857-1:2009).

Moreover, the fluorescence radiation has a greater effect from a biological point of view than the higher-energy scattered radiation that the apron blocks. [6]

In addition, the Category I standards required the determination of the lead equivalent at only one single X-ray tube voltage. As previously shown on page 9 in Figs. 9 and 10, the lead equivalent for lead-free or lead-reduced protective materials is highest around an X-ray tube voltage of about 90 kV. Therefore, if one selects this voltage for the determination of the lead equivalent according to the outdated measuring methodology I, the standard would be officially fulfilled, but the wearer would unknowingly be protected far less than assumed when working with other X-ray tube voltages.

[4] Schlattl H et al: *Shielding properties of lead-free protective clothing and their impact on radiation doses.* Med. Phys. 2007, Vol. 34, pp. 4270-4280

[5] Schöpf T et al: *Radiation Protection Clothing in X-Ray Diagnostics – Influence of the Different Methods of Measurement on the Lead Equivalent and the Required Mass.* Fortschr Röntgenstr 2016, Vol. 188, No. 08, pp. 768-775

[6] Regulla DF et al: *Patient exposure in medical X-ray imaging in Europe.* Radiat Prot Dosimetry 2005, Vol 114 (1-3), pp. 11-25w

Additional PPE Products for Protection Against Radiation

Even when all criteria have been considered when choosing your apron, there are still some delicate parts of the body, which are not protected. As a first step, you should always use on-site radiation protection, such as table-mounted lower body protection and ceiling-mounted protective shields. Unfortunately, this is not always possible.

1 Eye Protection

The human eye is incredibly sensitive towards ionizing radiation, and thus, should be protected with, for example, X-ray protective glasses. Particularly important is the correct fit of the glasses: The X-ray protective glasses must fit particularly tight to the cheeks and the sides of the user's face. The reason for this is that the secondary radiation emitted from a lying patient does not only hit the front of the eye lenses but rather comes from below or from the sides at different angles. [7]

2 Head Protection

Without effective on-site ceiling mounted scatter radiation protection, the skull can be exposed to a high amount of radiation depending on the procedure and exposure time. In these cases, it is advisable to supplement your protective clothing with a radiation protective cap. However, it should be taken into account, particularly with closed caps, that the cap, whilst fully protecting the skull, limits the heat dissipation over the skull.

3 Thyroid Protection

Regardless of the on-site radiation protection, a radiation protective apron should always be supplemented with some form of thyroid / sternum protection, as the thyroid is an organ which is particularly sensitive to radiation. [8] It is important to make sure that the thyroid protection and the protective apron completely overlap on the front so that there are no gaps in the radiation protection.

4 Shoulder Protection

There is hematopoietic bone marrow in the shoulder joint which should be protected. [1] In workplaces where you usually stand with your side towards the radiation source (e.g. in cardiac catheter laboratories), the radiation protective apron should at least have one sleeve.

Sleeves are also particularly well-suited for preventing the disadvantages of arm cutouts that are too large. The extra radiation protection material ensures that the particularly delicate breast tissue is no longer exposed.

5 Hand Protection

The hands are almost always closest to the patient and consequently to the source of the scattered radiation. As in the entire field of radiation protection, the idea of optimizing the radiation protection also applies here. This means that any possible measure to minimize exposure to radiation must be taken. One option are X-ray absorbing, sterile gloves. Nowadays, the characteristics of these gloves are so similar to conventional surgical gloves that they can be integrated into the radiation protection concept without any problems.

[7] Hristova-Popova J et al: *Risk of radiation exposure to medical staff involved in interventional endourology.* Radiation protection dosimetry 2015, 165(1-4), pp.268-271

[8] Adamus R et al: *Strahlenschutz in der interventionellen Radiologie.* Der Radiologe 2016, 56(3), pp.275-281

[1] Cristy, M., 1981: *Active bone marrow distribution as a function of age in humans.* Physics in Medicine & Biology 2007, 26 (3), p.389

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