Radiation protection aspects of radiation synovectomy procedures

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Introduction
Mono-arthritis may be a presenting feature for a variety of inflammatory arthropathies such as those associated with rheumatoid arthritis or psoriatic arthritis. Such patients can be troubled by a single persistently inflamed and swollen joint when other involved joints have improved in response to systemic therapy (eg methotrexate). Such persisting synovitis, involving excess growth of the synovial tissue within the knee, contributes to an ongoing inflammatory process. This can lead to excess synovial fluid and progression of structural damage, reducing mobility and contributing to ongoing pain and swelling. Patients usually undergo surgery but if symptoms persist, a radiosynovectomy (also referred to as a radiosynoviorhesis) can be considered.

A radiosynovectomy involves a rheumatologist placing a needle within the synovial cavity. They then aspirate the synovial fluid from the knee using the syringe. Following this, 185MBq of Yttrium-90 silicate/citrate is injected, followed by a local anaesthetic and a steroid solution.

What is Yttrium-90 silicate/citrate?
Yttrium gets its name from the village of Ytterby (Sweden) where it was discovered in a mine in 1787. Yttrium-90 silicate/citrate is a radiopharmaceutical produced in France by CIS Bio international and supplied in the UK by Alliance Medical. Yttrium-90 is a pure beta particle emitter (max. energy of the beta particles is 2.2MeV, mean 0.935MeV), silicate/citrate is a ligand, which acts by binding the Yttrium-90 to the synovium membrane. Given the ligand properties of the Yttrium-90 to the synovium, there is potential for the beta particles to shrink this tissue, reducing the production of synovial fluid.

The beta particles also produce x-rays through bremsstrahlung. The amount of x-rays emitted from the patient’s knee is very low (10-25µSv per hour close to the skin surface).

Radiation protection issues
Yttrium-90 delivers a high dose rate to tissue. For an unshielded 5ml syringe, the dose rate at the active surface is 44mSv per hour per MBq. So for a 185MBq syringe, this equates to 88Sv per hour. To put this into context, the dose constraint for the skin of a non-classified radiation worker (150mSv per year) could be exceeded if they were to hold an unshielded syringe over the active area for one minute.

It is clear that Yttrium-90 poses a high risk to the skin of the operators and the patients. There is one case in the literature where skin necrosis has occurred.

However this is considered a rare occurrence, as aspirating the knee beforehand reassures the rheumatologist they will deliver the Yttrium-90 within the synovial cavity via the same needle.

Potentially, skin erythema could occur if accidental contamination were to happen and go undetected. The operator’s hands and patient’s skin are at greatest risk.

How we can minimise these risks?
The European Association of Nuclear Medicine guidelines outline the procedure but do not mention aspects of radiation protection. Locally, a risk assessment was performed which identified key parts of the procedure where the greatest risk to skin from contamination can arise. Methods were devised to reduce each of these risks, which form the basis of the practical radiation techniques that we use to deliver this treatment as safely as possible.

Operators
We recommend employing a minimum of three operators: A clinical scientist and/or technologist, responsible for radiation protection; a rheumatologist for clinical cover. ie insertion of the needle in the knee and performing the Yttrium-90 injection under an ARSAC certificate; and finally a clinical scientist and/or technologist, responsible for radiation protection; a rheumatologist for clinical cover.

Continuity of the environment
A spacious clinic room should be set aside for this procedure, as it needs to accommodate a couch, three operators, the patient and possibly their companion. We always use the same room, which has the benefit of keeping the ergonomics the same. If a contamination incident did occur, the activity should be in a predictable location which makes it easier to detect.

Equipment
All essential equipment can be found to hand in most nuclear medicine departments.

Monitors
To check for contamination, a handheld Geiger radiation monitor and also a dose rate meter (with a beta-γ mode) are essential.

Syringe shields
Tungsten syringe shields can be used to shield the Yttrium-90 syringe. These have been shown to provide radiation protection capabilities as effectively as conventional perspex syringe shields.

Syringe carriers
To transport the full Yttrium-90 syringe, a lead lined syringe carrier is required. The dose rate from this is very small at <5µSv per hour. This carrier is also used to transport the syringe post injection to the radioactive waste decay store.
Radioactive waste sharps bin

To enable best practical means of disposal, a large sharps bin is required to contain any other material that may be contaminated with low levels of Yttrium-90 during the procedure (sets of gloves, cotton balls, paper towels and other syringes). There is a potential for this bin to contain levels of Yttrium-90 that could give a significant beta dose rate at its surface. Therefore it should ideally be shielded during use and when transported back to the waste store.

Miscellaneous

Miscellaneous accessories such as decontamination spray, needles, gloves, alcohol wipes, tweezers, cotton balls, safety glasses and gowns are all required. We place these in a lightweight toolbox for convenience.

World Health Organisation (WHO) pre-surgical checklist

As with any surgical procedure, a WHO checklist is essential and, once performed, provides confidence to all staff that they are safe to proceed with the procedure and can challenge others if they are concerned about the safety of the process. Contained within this is a prompt to perform standard IRMER checks (patient demographics, referral details, syringe, and justification). It also prompts to obtain a signature on the consent form.

Procedure step-by-step

The patient lies on a couch which can be raised up and down to provide good ergonomics, as shown in figure 1. Full consent to take and share these photos was given by the patient.

A layer of absorbent paper towel (to trap any potential contaminant) and a plastic bag (to stop any contaminant coming in contact with the couch) is placed underneath the patient. An incontinence pad with a hole cut out of the middle is draped over the patient’s knee.

There is always a worry with any injection that the contents of the syringe could ‘blow back’ onto the operator. In practice this has never happened but just in case, the following clothing is worn: The rheumatologist and technologist wear gowns, two sets of gloves each (double-gloves) and eye protectors.

In figure 1, the rheumatologist (left) is aspirating the knee with a large syringe. Patient compliance is important, so to reduce pain the injection site is anaesthetised with cold spray beforehand. The synovial fluid is poured into a disposable cup, which is eventually emptied down a sluice.

The shielded Yttrium-90 injection is placed within the lead lined syringe box and positioned within easy reach (bottom left of figure 1). A large sharps bin is positioned at the end of the couch.

The aspiration syringe is disconnected from the needle, which must remain within the knee (post aspiration, it is in the correct position to deliver the Yttrium-90 to the correct part of the knee).

Two cotton balls are placed beside the needle as shown in figure 2. These are put in place to capture any leaked Yttrium-90 during the injection which could drip on to the patient’s skin. Also, when the syringe is disconnected from the needle, there may be a small amount of backflow and the cotton balls are there to capture it before it reaches the patient’s skin. To protect the technologist’s fingers, tweezers are used to hold the balls in place beside the needle, thus putting some distance between any activity and their fingers.

The shielded Yttrium-90 syringe is carefully passed to the rheumatologist by the clinical scientist. They remove the cap which is placed in the waste bin. The syringe is connected to the needle in the patient’s knee and it is injected steadily as shown in figure 3.

After injection, the syringe is removed and placed in the lead lined syringe shield. The patient is then injected with the steroid (Depo-Medrone 80mg) and the local anaesthetic (2% lignocaine). This also flushes the residual Yttrium-90 within the needle into the knee.

The syringe and needle are finally removed and placed in the lead lined injection box. A small plaster is placed over the injection site.

Skin contamination checks

All contamination checks are performed by the clinical scientist as they have had minimal contact with the Yttrium-90. To ensure there is no skin contamination on the patient’s knee, a dosimeter is used to measure beta and x-ray dose rate levels directly above their knee at a distance of approximately 5cm, as shown in figure 4. A typical dose rate from the betas and x-rays is in the order of 10 to 25µSv per hour.

If the dose rate in beta mode is much higher than in x-ray mode, skin contaminant is suspected and we would begin swabbing the skin with small alcohol wipes to check for and remove contamination.

The hands of the rheumatologist and technologist also require checking using the Geiger monitor. Particularly attention is given to their fingertips after they have removed their gloves.

Imobilise knee with a splint

The patient is fitted with a splint to ensure the Yttrium-90 remains in place within the knee and has time to bind to the synovium tissue. Figure 5 shows splints in place post treatment. This patient has had both knees treated, which is relatively uncommon. They are also asked to undertake minimal physical activity for the next 48 hours. For this reason, the patient is often accompanied by a companion to help transport them home.

Room survey

After the patient has left, a room survey is conducted using the Geiger monitor. If any contaminant is found, standard decontamination procedures are used. All towels used to clean up contaminant can be placed in the large sharps bin.

Dealing with waste

Yttrium-90 activity within the used syringe is predictable (~10%). This can be placed directly into the long-lived waste store in nuclear medicine, after it has been transported using the lead lined syringe carrier.

Obtaining Yttrium-90 activity levels is difficult due to the nature of variable Bremsstrahlung x-ray production. Therefore, estimates of waste activity within the sharps bin using conventional equipment found in nuclear medicine can vary significantly. Three simple methods of measurement using handheld radiation instruments yielded values between 5 and 28MBq for the same bin. Locally, the method that produced the maximum activity estimate is used for waste records.

Further contamination checks

All equipment used to draw up and store the Yttrium-90 will require checking for contamination before being put back into use (eg syringe carriers, syringe shields).

Summary

- Yttrium-90 synovectomy for arthritic joint conditions is a proven technique for treating the problems associated with excess synovial fluid.
- Handling Yttrium-90 safely does require operators with the knowledge and skill to use appropriate radiation protection techniques to minimise the risk of a potentially harmful dose to the skin.
Equipment and expertise to deal with this procedure can be found in most nuclear medicine/radiopharmacy departments.

A clinic conducted by a rheumatologist, clinical scientist and a clinical technologist provides a team that can deliver a safe and effective procedure.

References

Figure 1
Aspiration of the knee.

Figure 2
Set-up of cotton balls to trap any Yttrium-90 during the injection to minimise the risk of skin contamination.

Figure 3
Injection of the Yttrium-90 using a tungsten syringe shield which is effective at shielding Yttrium-90.

Figure 4
Post injection skin contamination check of the knee using a dose meter to record beta and x-ray dose rate.

Figure 5
Post treatment splint to reduce mobility and ensure the Yttrium-90 silicate/citrate binds to the synovium (bilateral treatment).