# Hemodialysis of chronic kidney failure patients requiring ablative radioiodine therapy

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**Ablative radioiodine therapy is the standard treatment for thyroid carcinoma, but as $^{131}$I is predominantly cleared by renal excretion, its clearance will be reduced in patients with chronic kidney disease, particularly in anuric patients on dialysis. The high dose of radioactivity used in the procedure results in an increased risk of radioactive exposure to the patient, the dialysis staff, and the machinery. Here, we describe how to successfully hemodialyze patients with chronic kidney failure requiring ablative $^{131}$I therapy for thyroid cancer while minimizing risks to the patient and dialysis staff. With appropriate training, hemodialysis treatments can be safely delivered to patients receiving radiotherapy.**

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Although solid organ malignancy, in general, is not increased in end-stage kidney failure patients treated by regular dialysis compared with the general population,[1] patients can develop internal malignancies, which may require chemotherapy.

Ablative radioiodine ($^{131}$I) therapy is the standard treatment for thyroid carcinoma, and $^{131}$I is predominantly cleared by renal excretion, but clearance will be reduced in patients with chronic kidney disease and, in particular, anuric patients established on dialysis. As the dose of radioactivity is designed to be ablative, this potentially could result in an increased risk of radioactive exposure to the patient, the dialysis staff involved, and the dialysis machine.

Only a few centers in the UK have both the appropriate European Union license for both providing and disposing of this therapeutic radioactive isotope,[2] in combination with appropriate hemodialysis facilities.

$^{131}$Iodine is predominantly a beta radiation emitter, and thus there is a potential substantial risk of radiation exposure to the dialysis staff, due to both the close proximity of the staff to the patient and the contact time, including the preparation of the hemodialysis machine, needling the fistula, patient connection, and then monitoring of the hemodialysis treatment.

We reviewed our clinical practice for treating such dialysis patients. A multiprofessional team of renal, oncology, radiation protection, and projects department staff was assembled to identify the risks to all concerned. We report our experience of how to minimize the potential risks, and provide patients with successful $^{131}$I ablative therapy.

## RESULTS

After a trial hemodialysis session, a standard clinical ablative $^{131}$I dose of 3000 MBq (megabecquerels) was administered and the patient was nursed in isolation in his or her room, with staff protected by lead shields.

On the third day after admission, the first 4 h hemodialysis session took place some 39 h after radioiodine administration, when the radioactivity detected was 38 μSv and 11.1 μSv h$^{-1}$, at a distance of 1 and 2 m, respectively, from the patient. Once the machine had been checked and prepared, it was transferred from the shower room to the patient's room by the technician (Figure 1), and the dialysis nurse connected the patient to the machine by inserting two

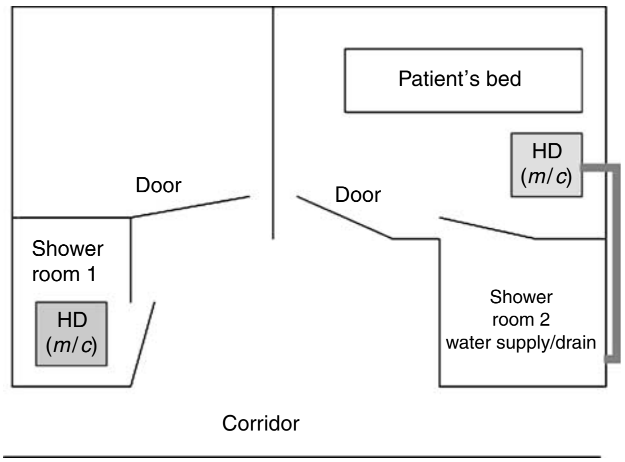


**Figure 1 | Schematic plan of section of oncology ward.** The dialysis machine was prepared in the adjacent shower room—shower room 1 using a potable water supply. The dialysis machine and portable reverse osmosis unit were then moved into the patient's room and connected to a potable water supply and drain from shower room 2.

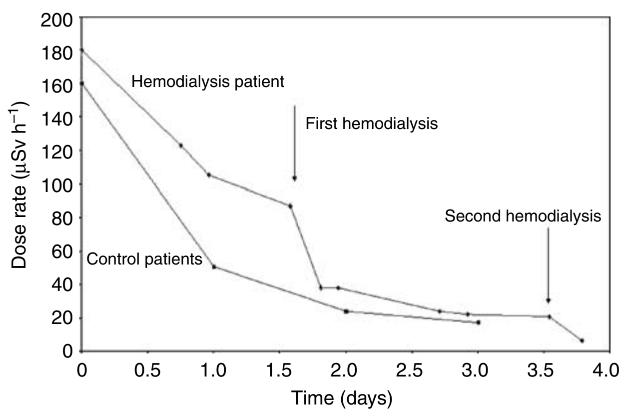


**Figure 2 | Fall in $^{131}$I radioactivity emitted following a standard clinical ablative dose of 3000 MBq, as measured 1-m distance from both our example hemodialysis-dependent patient and cancer patients with normal renal function.**

needles into a forearm fistula. Once stabilized on dialysis, the nurse left the room, and returned at regular intervals to check pulse, blood pressure, and machine blood volume, on-line clearance, and access monitoring. The patient had a buzzer alarm for safety. As expected, patient radioactivity fell during dialysis (Figure 2). Following dialysis, the hemodialysis machine was put into an endless rinse mode to remove any contaminating radioactive material. After 1 h, the radioactivity level measured in the drain line was minimal, and no different to background. The dialysis machine was then moved back to the shower room and put into a heat disinfect mode for 40 min.

The hemodialysis treatment was then repeated, 2 days later, when the radioactivity was much less (Figure 2). The patient was discharged the following day, as the radioactivity had returned to background levels, to return to normal outpatient hemodialysis.

The dialysis nurses and dialysis technicians wore finger and waist dosimetry devices. When these were subsequently read, the amount of radiation exposure was below the threshold level of detection of both these monitors (<100 μSv). As these standard devices cannot be read instantaneously, health-care workers also carried real-time recorders, and the results are set out in Table 1.

**Table 1 | Radioactive doses recorded, using the real-time dose meter monitor (Bleeper Sv, Bartec Technology, Camberley, Surrey, UK), from dialysis staff**

| Dialysis | Dialysis staff | Time (min) | Radiation dose (μSv) |
|---|---|---|---|
| 1st dialysis | Nurse 1 | 28 | 12 |
| | Technician 1 | 28 | 7 |
| 2nd dialysis | Nurse 2 | 30 | 3 |
| | Technician 2 | 18 | 0 |

Time refers to time spent in the patient's room.

**Table 2 | Anticipated problems of administering $^{131}$I to a hemodialysis patient**

| Potential problem | Risk of radiation exposure |
|---|---|
| Reduced $^{131}$I clearance | Patient |
| Dialysis staff exposure | Dialysis nurse |
| | Dialysis assistant |
| Machine contamination | Dialysis technician |
| Blood spills | Nursing staff |
| | Cleaning staff |

## DISCUSSION

The key management is to provide the patient with $^{131}$I radioablative therapy and yet to minimize radioactive exposure to health-care workers (Table 2). It was impracticable to move the radioactive patient to the dialysis center, so dialysis had to be brought to the patient. This required installing potable (drinking) water, to comply with home hemodialysis water installations, and then providing suitable water of chemical and microbacteriological quality.[3–5] The predicted radiation exposure to the dialysis nursing staff was 230 μSv. However, by providing radiation protection training, and having one preradioablative hemodialysis session, in which the staff wore appropriate clothing, and connected and disconnected the patient, with the lead shields in place, reduced the subsequent maximum radiation exposure to 12 μSv (approximately equivalent to half a chest X-ray; Table 3). Staff members were equipped with extremity as well as whole body monitoring, as exposure to β irradiation is dependent upon distance from the radiation source The cumulative finger and truncal exposure was below the level of detection of these monitors (<100 μSv). The instantaneous radiation exposure dose recorded by the dialysis nurse performing the first hemodialysis treatment is approximately equivalent to 5 days worth of exposure to the natural

**Table 3 | Comparative radiation exposure with radiological investigations and risk of developing a malignancy due to radiation exposure[6]**

| Procedure | Effective dose (mSv) | Risk per million |
|---|---|---|
| Knee X-ray | 0.003 | 0.15 |
| Chest X-ray | 0.02 | 1.0 |
| Pelvis X-ray | 0.7 | 35 |
| Lumbar spine X-ray | 1.2 | 60 |
| Tc-99m bone scan | 3.0 | 150 |
| Barium enema | 7.2 | 360 |
| CT scan abdomen | 10 | 500 |
| International air flight 8283 km | 0.02 | 1 |
| Annual natural radiation in UK | 2.2 | 110 |

Technetium-labeled (Tc-99m) bone scan.
CT, computerized tomographic scan; UK, United Kingdom.

background radioactivity in London, and approximately less than half that with a routine chest X-ray (Table 3), and so was substantially less than that of previous reports.[7] The standard finger and truncal irradiation monitoring devices do not provide an instantaneous assessment of radiation exposure, but provide an assessment of total exposure. We therefore suggest the use of an additional electronic dose meter for real-time monitoring, so that in the event of a radioactive spill, immediate assessment of radioactive exposure can be readily made and, if necessary, medical personnel can be promptly substituted.

Time spent in the immediate vicinity of the patient was minimized, by preparing the dialysis machine in the adjacent shower room, and then transferring it into the patient's room. Once the patient was stabilized on dialysis, the nurse and technician left the room. The nurse then returned to perform routine observations, and then at the end of the session to disconnect the patient. The dialysis machine was endlessly rinsed, until the radioactivity in the dialysate waste had returned to baseline, and then moved and stored in the shower room, until the second dialysis session. To reduce individual staff radiation exposure, a second dialysis nurse and dialysis technician supervised the second treatment. Other centers have used different dialysis nurses to connect, supervise, and then disconnect the patient during the dialysis session, so as to reduce individual exposure.[8]

The dialysis machine was rinsed in the patient's room, until dialysate and machine radioactivity had returned to background levels, and then disinfected as per standard. Following rinsing and disinfection after the second dialysis, the dialysis machine was subsequently returned to the outpatient dialysis center for general patient usage, as no excess radioactivity could be detected.

This hemodialysis patient received calculated radiation doses of approximately 168 Gray (Gy) to the thyroid and 396 Gy to the bone marrow, compared with the standard doses of 69 Gy to the thyroid and 165 Gy to the bone marrow, respectively, to patients with normal renal function. The increase dose was due to the reduced clearance of $^{131}$I in the end-stage kidney failure patient, even though $^{131}$I was effectively cleared by hemodialysis[9] Excessive doses of ablative $^{131}$I have not been shown to provide additional irradiation of the thyroid cancer, but they rather increase radiation exposure to the bone marrow.[9,10] However, this potential excessive radiation exposure to bone marrow is derived from mathematical models rather than clinical studies, as some 70% of radioactivity is taken up into the thyroid gland, and in patients with normal renal function, rapid renal excretion prevents toxic bone marrow uptake. However, in patients with end-stage renal failure, particularly those who are anuric, potentially up to 30% of the radioactive dose could be taken up into other tissues including the bone marrow. To prevent such potential over dosage, some centers have recommended a dosage reduction, varying from as low as 18% to up to 50%.[10,11] However, too large a reduction could potentially result in a failure to deliver a radioablative dose of $^{131}$I. In the illustrative case described, the patient received a standard dose of 3000 MBq. An alternative would be to perform an earlier hemodialysis session if the patient radioactivity detected was much greater than expected, to help increase $^{131}$I removal.[12] This would be important in those cases when larger doses of ablative radiotherapy ($>$3000 MBq) are used.

Thus, with careful thought and appropriate training, hemodialysis treatments can be safely delivered to radioactive patients. The dialysis staff found the pretreatment dialysis session very instructive, by practicing connecting the patient to and disconnecting from the dialysis machine, while wearing protective clothing and working behind the lead shields.

## MATERIALS AND METHODS

It was quickly realized that the risks to other patients, visitors, and staff could not be adequately controlled if the patient were to be moved from the oncology ward, after the $^{131}$I treatment, to the outpatient hospital dialysis unit. Although the oncology ward had the appropriate license for administering and disposing of $^{131}$I, there were no facilities for routine hemodialysis treatments.

It was not practical to provide dialysis quality water[3] to the oncology ward, so a potable (drinking) water supply, protected by two nonreturn valves in series to comply with UK regulations,[4] was installed into the bathroom leading from patient room 19 (Figure 1) and also to the small shower room close by. Our stand-alone intermittent hemodialysis water treatment system consists of two (600 mm × 75 mm) powdered, activated carbon (2 μm) filters in series (KX Industries, LP. Connecticut, USA), a single patient reverse osmosis monitor (WRO 100, Gambro AB, Lund, Sweden), and a hemodialysis machine (4008H Fresenius Medical Care FMC, Bad Homberg, Germany) fitted with an inline ultrafilter (Diasafe, FMC, Bad Homberg, Germany). Such a water treatment setup has been shown by our Dialysis Technical Services team to provide dialysis fluid of an appropriate chemical and microbiological quality.[3,5] A drain line was also fitted to allow contaminated dialysate to enter the approved waste drain in the room.

Iodine[131] is mainly a beta radiation emitter and the best way to minimize any exposure risks to nursing and allied medical staff is to reduce the amount of close contact time with the patient (Table 2). To help achieve this, the adjacent shower room (Figure 1) was used as a preparation area, so that the reverse osmosis and hemodialysis machine could be set up and put through mandatory disinfection, functional testing, and then lined and primed, physically away from the patient. The hemodialysis machine could then be power-failed, by disconnection of the power supply, moved into the patient's room, and then reconnected to the electrical supply. As the dialysis machine has a battery back-up system, it reverts to the previous state, without the necessity to repeat the setup cycle, allowing prompt patient connection.

As with any electrical or mechanical equipment, there is a risk of a technical fault occurring,[13] and in the worst-case scenario—a machine failure. A spare hemodialysis machine, already primed and prepared, was kept in the dialysis unit on standby.

All staff to be involved in providing hemodialysis treatment to the patient were given appropriate radiation protection training. To minimize staff exposure, all staff wore theater scrub clothing, rather than their usual hospital uniforms and/or clothing, and then appropriate protective clothing (overshoes, gloves, and apron). Two lead shields were placed in the room, a larger 5-cm-thick shield at the entrance to the room, primarily designed to decrease the dose rates outside the room to acceptable levels, and a smaller bedside shield, for the nursing staff to work behind.

To help with the training of the staff, the patient had one hemodialysis treatment in the room, before the administration of $^{131}$I. The dialysis nurse, with the help of the technical staff, connected the patient to the machine. This took about 5–7 min and was carried out behind a lead protection panel, and all staff wore protective equipment and radiation monitoring devices, including an electronic dose meter for real-time monitoring (Bleeper Sv, Bartec Technology, Camberley, Surrey, UK). Besides whole body and extremity radiation monitors, staff also wore finger monitors, as the blood lines would be radioactive, and potentially there would be increased risk of radiation exposure while connecting the patient to and disconnecting the patient from the dialysis machine (Global Dosimetry Solutions, Fountain Valley, CA, USA).

Following completion of the dialysis treatment, the machine was rinsed for approximately 60 min and checked for radioactivity, and once down to background activity, it was returned to the shower room (Figure 1). All dialysis disposables were left in the patient's room in a special bin and removed by the radiation protection team. In case of blood spills or dialysate leaks, the radiation protection team were available on standby to help with decontamination.

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