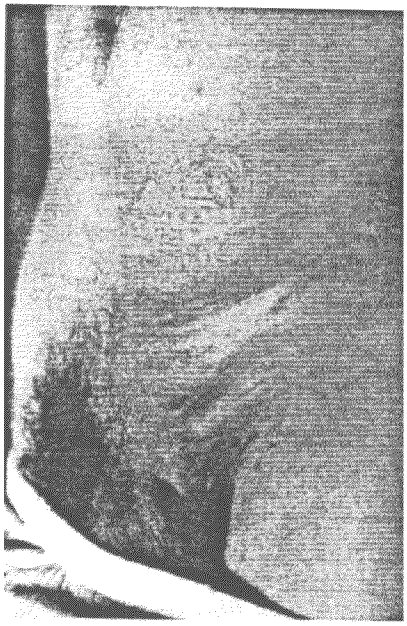

Image 9. Permanent epilation, pigmentation and severe subcutaneous fibrosis after left groin irradiation The patient also had limitation of movement of the left hip due to overexposure.

Many of the patients examined had received skin doses in excess of 52 Gy, often with fewer than 20 fractions. This aggravated the effects even further. These higher doses resulted in severe fibrosis with fixed skin in some patients and skin necrosis in others. For quite a number of the patients examined, skin effects were exacerbated by treatment with the anterior field one day and the posterior field the following day, rather than treating with each field every day. This effectively reduced the number of skin and superficial tissue fractions listed on the physics sheet by half. This should be kept in mind when the total doses are examined.

Regrowth of hair often occurs even when the radiation doses to the skin are high. A number of patients had permanent epilation, which attests to the high skin doses (Images 10 and 11).

Examples of such cases included:

Patient No. 44, who had received 31 Gy in 2 fractions or 15.5 Gy per fraction. This patient had ulceration of the vulva on both sides. This treatment is calculated to be biologically equivalent to about 57 fractions of 2 Gy each for a total dose of about 115 Gy.

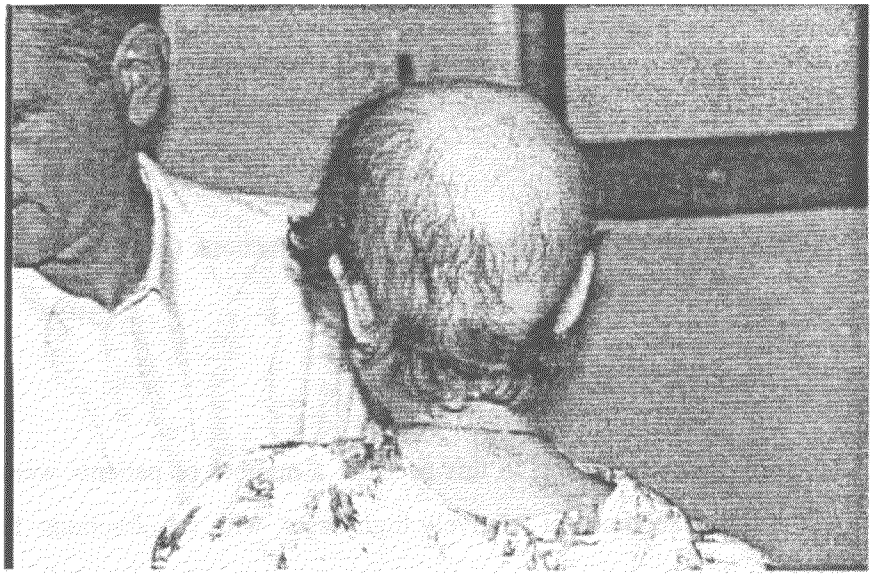

Image 10. Patient with permanent epilation as a result of overexposure. The patient is at high risk for late brain necrosis and spinal cord injury

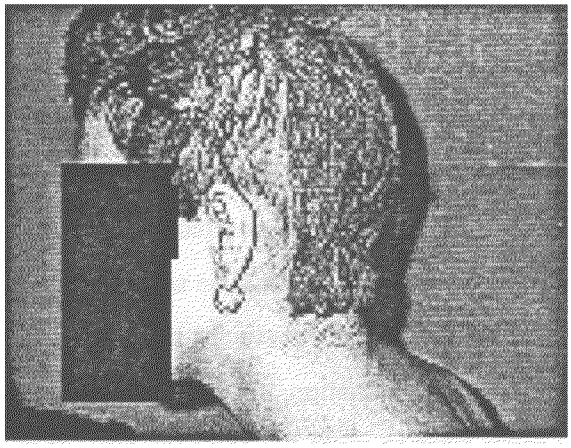

Image 11. A second patient with permanent epilation as a result of overexposure. The patient is at high risk for late brain necrosis and spinal cord injury.

Patient No 8, who had received 70 Gy in 20 fractions but with alternating day treatment. Effectively, the skin had received 56 Gy in 10 fractions or 5.6 Gy per fraction. This patient had severe sacral fibrosis.

Patient No 62, who had received more than 43 Gy in 15 fractions (more than 3.1 Gy per fraction). This patient may have received alternating fields resulting in fractions of at least 6.2 Gy each to the skin, and had severe sacral fibrosis.

Patient No. 39, who had received about 58 Gy in 14 fractions (about 4.1 Gy per fraction). This patient had severe deep fibrosis of the inguinal region with limitation of motion. There was also permanent epilation.

Patient No. 106 was a child who had received 62 Gy in 25 fractions (2.5 Gy per fraction in alternating fields) and who had permanent epilation.

Patient No. 109 was a child who had received 58 Gy in 20 fractions (3.0 Gy per fraction) to the cranium. He had permanent epilation.

5.3. GASTROINTESTINAL SYSTEM

The intestine is very sensitive to radiation. In this accident a number of patients were irradiated to quite large fields of the lower abdomen at relatively high doses, with few fractions. Severe chronic radiation injury of the small bowel usually presents as constipation and abdominal pain, often with stenosis, and often as an acute abdomen with ulcerations, infarction, fistulas and perforation. Surgery is the only form of treatment for injuries to the small intestine. Small bowel injury can also present as a malabsorption syndrome with anaemia.

Radiation injury of the rectum and sigmoid often presents with rectal bleeding 6–12 months following irradiation. If the injury extends into the sigmoid colon, bloody diarrhoea is often present. Treatment is usually conservative and surgery is not recommended. Even a biopsy can cause massive haemorrhage. Rectal stenosis can also occur. The scoring system used for radiation injury of the gut is shown in Table III. The dose–effect curve for severe complications of the large bowel is very steep. With standard treatment fractionation, the incidence of severe complications is 10% at 50 Gy and 40% at 60 Gy. Larger fraction sizes weigh more heavily in the incidence of chronic effects than in that of acute effects. The incidence of complications is also directly dependent upon the volume treated. Large treatment fields were often used for these patients.

TABLE III. ACUTE AND LATE RADIATION MORBIDITY SCORING CRITERIA (REPRODUCED FROM SCHERER [17]) (RTOG/EORTC)[a]

Organ/tissue	0	Grade I	Grade 2	Grade 3	Grade 4
Acute radiation morbidity scoring criteria					
Upper GI	No change	Anorexia with ≤5% weight loss from pretreatment baseline; nausea not requiring antiemetics; abdominal discomfort not requiring parasympatholytic drugs or analgesics	Anorexia with >15% weight loss from pretreatment baseline; nausea and/or vomiting requiring antiemetics; abdominal pain requiring analgesics	Anorexia with >15% weight loss from pretreatment baseline, requiring nasogastric tube or parenteral support; vomiting requiring nasogastric tube or parenteral support; abdominal pain severe despite medication; haematemesis or melena; abdominal distention (flat plate radiograph demonstrates distended bowel loops)	Ileus, subacute or acute obstruction, perforation, GI bleeding requiring transfusion; abdominal pain requiring tube decompression or bowel diversion
Lower GI including pelvis	No change	Increased frequency or change in quality of bowel habits not requiring medication; rectal discomfort not requiring analgesics	Diaorrhea requiring parasympatholytic drugs; mucous discharge not necessitating sanitary pads; rectal or abdominal pain requiring analgesics	Diaorrhea requiring parenteral support, severe mucous or blood discharge necessitating sanitary pads; abdominal distension (flat plate radiograph demonstrates distended bowel loops)	Acute or subacute obstruction, fistula or perforation, GI bleedin requiring transfusion; abdominal pain or tenesmus requiring tube decompression or bowe diversion
Late radiation morbidity scoring criteria					
Small/large intestine	None	Mild diaorrhea; mild cramping; bowel movement 5 times daily, slight rectal discharge or bleeding	Moderate diaorrhea and colic; bowel movement >5 times daily; excessive rectal mucus or intermittent bleeding	Obstruction or bleeding requiring surgery	Necrosis; perforation; fistula
Liver	None	Mild lassitude; nausea dyspepsia; slightly abnormal liver function	Moderate symptoms; some abnormal liver function tests; serum albumin normal	Disabling hepatic insufficiency; liver function tests grossly abnormal; low albumin; oedema or ascites	Necrosis, hepatic coma encephalopathy

[a] Grade 5: Death directly related to radiation effect.

Some examples of patients examined with these complications included:

Patient No. 83 had received a total dose of 72 Gy (AP/PA) to the bowel in 25 fractions and 12 Gy from lateral fields in 5 fractions. The patient had continual rectal bleeding, diarrhoea, anaemia and weight loss. This treatment is calculated to be biologically equivalent to about 50 fractions of 2 Gy each for a total dose of about 100 Gy to the bowel.

Patient No. 78 had received 68 Gy in 25 fractions (2.7 Gy per fraction) of pelvic radiotherapy. The patient had continued diarrhoea and a 2 cm x 2 cm infected skin ulcer.

Patient No. 85 had received more than 49 Gy in 18 fractions, but with alternating fields every other day. The patient had rectal pain with ulceration and perirectal ulceration.

Patient No. 8 had received 56 Gy in 20 fractions (2.8 Gy per fraction) but with alternating fields every other day. The patient had occasional diarrhoea.

Patient No. 44 had received 25 Gy to the bowel in two fractions (12.5 Gy each). This treatment is calculated to be biologically equivalent to about 31 fractions of 2 Gy each for a total dose to the bowel of about 62 Gy.

5.4. CARDIOVASCULAR SYSTEM

Radiation induced changes of the heart have been reported in patients treated for Hodgkin's disease. Cardiomyopathy rarely occurs with standard fractionation schemes and doses of less than 40 Gy. Above this level, up to half of the patients will experience pericarditis. Patients show a more than 50% incidence of complications when the dose exceeds 60 Gy (standard fractionation). Increasing the dose per fraction has been shown to significantly increase the complications and incidence. At 50 Gy of standard fractionated radiotherapy (2.0 Gy per fraction) about 25–35% of patients will develop reduced ventricular function. Pericardial effusions due to radiation usually occur between 1–6 months after irradiation and in over 50% of patients who have received in excess of 60 Gy of standard fraction radiotherapy (Image 12). At least one patient examined clearly had pericarditis and a pericardial effusion requiring surgery.