Report of the Independent Review
commissioned by
The Royal College of Radiologists

into

Brachial Plexus Neuropathy following Radiotherapy for Breast Carcinoma

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FINDINGS

Patients’ morbidity

1. Brachial plexus neuropathy (BPN) is a rare but serious side effect of radiotherapy for operable breast carcinoma. It was identified in 48 of a sample of 126 patients (38%) who agreed to cooperate out of 249 members of RAGE, who were treated during the 14 year period 1980 to 1993 at 15 cancer centres. A conservative estimate of the total number of patients with operable breast cancer receiving radiotherapy at these centres during this time is 65,000.

2. The incidence of BPN due to radiotherapy (BPN/RT) appears to be falling. From the first 7 years we found 41 cases and from the second 7 years only 7 cases.

3. A further 2 patients with BPN due to surgery and a further 9 with BPN due to recurrence were identified, making a total of 59 patients with BPN (47% of the sample).

4. In 3 of the cancer centres visited we found no cases of BPN/RT among the patients’ notes we reviewed.

5. The time of onset of the first symptoms of BPN/RT ranged from during radiotherapy to 10 years after radiotherapy, but by 27 months over half of the patients with confirmed BPN/RT had symptoms.

6. Sensory symptoms in the hand were the commonest first symptoms of BPN/RT. Most patients went on to develop muscle weakness and 23 patients (48%) went on to develop a flail useless arm. Pain was a major feature in 34 patients (71%) and this was often very difficult or impossible to control.

7. Unusually severe late radiation changes were noted in other tissues. Severe subcutaneous fibrosis (scarring beneath the skin) was identified in 58 of the 126 patients (46%) and in some patients this led to a painful stiff shoulder and in others to a severely deformed breast.

8. Bone necrosis was recorded in 18 of the 126 patients (14% in contrast to an expected 1 to 2%), and this resulted in painful fractures of the ribs or clavicle in some, and extrusion of dead bone through the skin in others.

9. Lymphoedema of the arm was recorded in 46 patients (37%). Surgical dissection of the axillary lymph nodes plays a part in the causation of lymphoedema of the arm. The incidence is even higher when this is followed by radiotherapy. Today whilst there is more axillary surgery, radiotherapy is often given selectively for high risk cases only and very rarely after axillary surgery, and the risk has fallen to below 10%.

Methods of treatment

10. The methods of treatment used for the 126 patients have been carefully scrutinised and detailed in the report, including the type of surgery, details of radiotherapy and the use of cytotoxic chemotherapy, as all can play a part in subsequent morbidity.

11. The most obvious factor in this review was the association of BPN/RT with movement of the patient between the treatment of the chest wall and the treatment of the lymph nodes. There was a total of 98 patients where movement was relevant, and 34 of 47 patients where movement was apparent developed BPN/RT (72%), while only 12 did so out of 51 patients who were treated in a static position throughout (24%).

12. As described in the review, the biological effects of radiotherapy depend not only on the total dose delivered but also on the number and size of the individual treatments (called fractions), the intervals between the fractions and the overall time of the course of radiotherapy. Analysis of both total dose and fraction size showed a similarity in the patients with and those without BPN/RT.

13. The majority of patients (75%) were treated daily and 28 developed BPN/RT (37%). Of the patients treated in 5 fractions per fortnight, 18 of 33 developed BPN/RT (55%) and of the patients treated in 3 fractions per week, 1 of 13 developed BPN/RT (8%).

14. Accuracy of delivery of the dose prescribed was not felt to be a factor in this review. All doses were rechecked by the physicists and we found the Quality Assurance standards in all of the cancer centres visited to be adequate and improving rapidly towards the very high standards required today.
15 Relatively “high dose” techniques aiming for cure, with doses close to normal tissue tolerance were identified. In our opinion, these included (i) long courses of 5-6 weeks delivering 60 Gy or more in daily fractions; (ii) long courses of 5-6 weeks delivering 47 Gy or more in 5 fractions per fortnight; and (iii) short courses of 3 weeks duration delivering 40 Gy or more in 5 fractions per fortnight. These “high dose” techniques were identified in 36 patients and 25 developed BPN/RT (69%) plus 1 possible BPN/RT. When coupled with “moderate” movement of the patient during treatment, “high dose” techniques were associated with the development of BPN/RT in 21 out of 23 patients (91%).

Cancer centres

16 Details of the cancer centres visited are described in the report. In all centres there was striking progress in the total care of breast cancer patients in recent years.

RECOMMENDATIONS

The review is, of necessity, based on an unrandomised sample: our recommendations must therefore be treated with caution. They relate to modern practice and future research.

Modern practice

Patient selection

17 In our present state of knowledge, patients should receive cervico-axillary radiotherapy selectively and not routinely.

Patients’ position during radiotherapy

18 Patients receiving cervico-axillary radiotherapy and chest wall tangents should be treated throughout in a static position.

Dosimetry

19 On the evidence of the review, we were unable to advise on optimum radiotherapy dose and dose fractionation techniques. We advise caution with the “high dose” techniques, with one fraction per week techniques and with an additional boost to the base of the axilla.

20 We recommend that all fields, except the boost to the tumour bed, be treated at each treatment session.

21 Dosimetry of the axilla requires closer attention than it receives routinely today, with greater involvement of the physicists.

Protocols for breast cancer management

22 All cancer centres should have an agreed written protocol for breast cancer management which is subject to audit and reviewed regularly, so that advances and initiatives are not inhibited. For the same reason we cannot advocate a single national protocol in our present state of knowledge.

Organisation of breast cancer treatment

23 We agree with others, that all breast cancer patients should be looked after by a multi-disciplinary team of breast specialists with a wide knowledge of the disease, and that this team should include nurses.
Recognition of the relationship of breast cancer and brachial plexus neuropathy

Surgeons and oncologists need to be more aware of the brachial plexus syndromes which can arise in breast cancer patients, their causes and management.

Patients need acknowledgement, and when possible, an explanation of their symptoms whether or not these are thought to be due to their cancer or its treatment.

Future research

Recognising the limitations of an analysis based on a small self-selected group of patients, we have identified the need for the following research studies which might substantiate our recommendations. Some of this research is already under way.

Studies are needed of the variations in the anatomy of the axilla and in the positions of the brachial plexus during different movements, and their relationship to the customary bone landmarks and the skin marks used by clinical oncologists to define radiotherapy field limits.

Large scale survival studies are needed to show whether or not a relatively high dose of radiotherapy improves the survival prospects of identifiable patients with operable breast cancer. If this cannot be proven lower “safer” doses should be used.

Multi-centre studies of dose fractionation are needed to determine the optimum treatment for operable breast cancer. For example comparisons could be made of the efficacy of appropriate total doses (i) delivered in short and long overall treatment times and (ii) in daily fractions and 5 fractions per fortnight over 5/6 weeks. These studies could be carried out by the Royal College of Radiologists but would need funding.

Genetic studies of the variations in patient radiosensitivity are in progress.
It is important to state at the outset that serious side effects following radiotherapy for early operable breast cancer are not usual.

New breast cancer patients hearing about this report must not have their confidence shaken in either their specialists or their treatment. The patients studied in this report are a special, highly selected group who have had unusually severe side effects. The report does not minimise their suffering and we are grateful to them for making this study possible. The whole purpose of the report is to find out why they, and not the thousands of other patients treated, have suffered so much. These patients and the staff who treated them want to know what can be done to prevent it being repeated in other patients.

The report does not have all the answers. It cannot be a scientific study because the patients are self-selected and have not been compared with any other patients. Nevertheless, the valuable information gathered has made it possible to make practical recommendations about treatment in relation to dose and the position of a patient during radiotherapy, and to formulate hypotheses that can be tested in a more formal scientific manner.

During our visits to the cancer centres we were heartened to find so much recent progress in the total care of breast cancer patients. Treatment before 1985 and treatment in 1995 are very different and we are confident that the very severe side effects experienced by the patients in the review will continue to become even more rare in the future.

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1 Introduction

1.1 Brachial plexus neuropathy (BPN) is a rare but serious side effect of radiotherapy for operable breast carcinoma. Some of the patients who believed they were affected came together as a RAGE group (Radiation Action Group Exposure). They brought the matter to the attention of the public and asked the Royal College of Radiologists to investigate the cause of their injuries.

1.2 This independent report into brachial plexus neuropathy in patients with breast carcinoma was commissioned by the Royal College of Radiologists and funded by the Clinical Audit Unit of the NHS Executive.

1.3 The subject of the report is important for patients with operable breast carcinoma for whom radiotherapy is prescribed, for people involved in the science and clinical practice of radiotherapy and for those responsible for standards of care in the National Health Service.

1.4 We have therefore tried to use language which will ensure a common understanding of what we have found and what could be done about it. There is a simple Glossary of medical terms at Section 9 on page 30.

1.5 We offer practical recommendations as a demonstration of our own sympathy with members of RAGE who have suffered distress to any degree.

1.6 In introducing our report, we wish to express our gratitude for the help that we have received from the Executive Committee and Officers of RAGE and the patients who gave their consent to inclusion in the investigation. Some patients did not give their consent because they feared that this might prejudice their planned litigation, and this we understand.

1.7 We are also most grateful to the staff of the cancer centres which we visited for their generous help. It was particularly obvious that the staff of every centre were keen to find out why patients had been so distressed and how this could be prevented in the future.

1.8 Our appreciation goes, not least, to Mr C.J. Squire, Clinical Audit Adviser at the Royal College of Radiologists, for all his help.

The Brachial Plexus

1.9 The brachial plexus is a bundle of nerves that arises in the lower neck (from the union of the anterior roots of the lower four cervical and the first thoracic nerves) and supplies power and sensation to the arm.

1.10 The plexus runs from the side of the neck and passes under the middle third of the clavicle (collar bone), across the axilla (armpit) and down the underside of the humerus (the upper arm bone) accompanied by blood and lymph vessels. Lying adjacent to the plexus in the lower neck and axilla are the cervico-axillary lymph nodes which drain the arm and the breast.

1.11 When the shoulder is abducted with the arm at right angles to the body (as it often is during radiotherapy for breast carcinoma), the brachial plexus runs horizontally, sloping diagonally backwards. Just above the mid-clavicle it lies about 3-4 cm below the skin, depending on the thickness of the overlying fat, but in the axilla it lies more deeply, frequently in mid-axilla.

1.12 When the arm is moved up above the head or down by the side the lower part of the plexus moves with the arm.

1.13 The sensory nerve fibres in the brachial plexus supply defined areas of the arm and hand (Fig 1).

1.14 Likewise the motor pathways are well defined.
1.15 Thus, the pattern of motor and sensory disturbance which can follow damage of the brachial plexus gives an indication of the site and extent of the damage. The opinion of a consultant Neurologist and nerve conduction studies may be required to make a precise diagnosis.

1.16 Brachial plexus damage can be caused by injury, by surgery, by radiotherapy or by tumour.

Breast Carcinoma

1.17 Breast carcinoma is the commonest malignant tumour in women in the United Kingdom accounting for 25% of all cases of cancer in women.

1.18 The management of early operable breast carcinoma has changed over the last fifteen years with many more patients being treated today with conservative surgery and radiotherapy, thus keeping their breast, rather than by a mastectomy (with or without radiotherapy).

1.19 The main role of radiotherapy, which like surgery is a local form of treatment, is to prevent local recurrence. When the breast is preserved, most cases will need radiotherapy to the breast and sometimes also to the lymph nodes, in case tumour has been left behind. It is possible that radiotherapy prolongs life in some early cases if the dose is adequate.

1.20 Adjuvant Tamoxifen and/or cytotoxic chemotherapy are systemic rather than a local treatments, and in selected cases have been shown to prolong life. They are used more often today than in the past.

1.21 Another important recent advance in the care of breast cancer patients has been the establishment of specialist teams of surgeons, oncologists, pathologists, radiologists, nurses and others, who work together and see a large number of breast cancer patients and thus gain a wider experience of early diagnosis and optimum management of individual patients, than do practitioners with a smaller more limited experience.

1.22 At the same time there has been a greater awareness of quality of life issues with the establishment of counselling services, lymphoedema and pain relief clinics, and a better availability of information on treatment options and prognosis.

1.23 This report looks at the changes in the facilities available, and the quality of care for breast cancer patients today and compares them with management in the recent past.

Adjuvant radiotherapy for breast carcinoma

1.24 There are many different techniques for delivering adjuvant radiotherapy. The volume irradiated will depend on the extent of the breast carcinoma, and the extent of the surgery performed. For some patient it is sufficient to irradiate the breast only, in others it is necessary to irradiate the breast and the lymph nodes. Individualisation of treatment is important.

1.25 The intact breast is usually irradiated with two opposed tangential fields which glance across the chest wall and include all of the breast, some of the underlying ribs and a segment of lung. Modern megavoltage machines such as a linear accelerator or a cobalt unit are used, and the depth of lung irradiated is kept to a minimum by identifying it with either an X-ray or an ultra-sound examination. Treatment is carefully pre-planned by the doctor, physicist, and radiographer team and a computer printout of the dose distribution across the breast and chest wall is obtained with the patient in the treatment position. The dose distribution can be modified to make
it more uniform by using wedged filters in the path of the beam in all, or some, of the treatment sessions, or by increasing the dose to high risk areas with an additional subsequent boost to the site of the tumour or the scar. For each patient treatment has to be individually planned. These variations are desirable.

1.26 When the breast has been removed, the chest wall may be irradiated by tangential fields as for the intact breast, or by a direct field of irradiation which treats only the superficial 3-4 cm of the chest wall, e.g. by electron beam therapy, where the depth of treatment can be controlled by varying the voltage of the treatment machine.

1.27 A boost dose to the site of the tumour and/or the excision scar is sometimes given. This can be given by further external radiotherapy, the machine used chosen according to the depth of irradiation required e.g. cobalt teletherapy or electron beam therapy, or by the temporary implant of radioactive material, often with iridium wire.

1.28 The main lymph nodes draining the breast lie in the lower neck above the clavicle and extend down into the axilla (the cervico-axillary chain of nodes). In the early 1980’s, it was common practice to irradiate these nodes as a routine. Today this is often given only for selected patients who have a high risk of recurrence. The radiotherapy techniques which are used to treat the volume containing these cervico-axillary nodes vary considerably in the United Kingdom (see Figs. 4a to 4d on page 21).

1.29 Doses and dose schedules also vary according to local custom.

1.30 A patient’s position during treatment also varies according to local custom.

1.31 These variations in technique, dose, dose schedule and patient position are reviewed in this report.

Unwanted side effects of radiotherapy

1.32 Side effects of adjuvant radiotherapy for breast carcinoma can be divided into early acute effects, which come on during or shortly after treatment, are temporary and last usually for up to a month after treatment, and late chronic effects which can come on weeks, months or years after treatment and tend to persist and get worse rather than better.

1.33 The acute early side effects vary with individual patients. For some the only symptom may be tiredness (lassitude), others with exactly the same treatment may experience in addition loss of appetite, reddening or even blistering of the irradiated skin, temporary difficulty in swallowing, and occasionally nausea and vomiting. These symptoms are not common.

1.34 The late side effects are more important because they persist. Again there is a difference between individual patients receiving the same dose but there is also an increased incidence of side effects in relation to the dose received by the tissues.

1.35 Late changes in the skin range from no change, to severe telangiectasia and dyspigmentation (changes similar to those following a burn) and very occasionally chronic ulceration of the skin. With modern megavoltage machines the maximum dose lies beneath the skin and severe late skin changes are unusual unless the skin has been irradiated deliberately as part of the individual planning of the patient’s treatment, such as when electron therapy is used to boost the dose to the tumour bed.

1.36 Some subcutaneous fibrosis (scarring beneath the skin) is fairly common after megavoltage radiotherapy but it is rarely severe. Mild fibrosis can alter the contour of the breast. Severe fibrosis distorts and shrinks the breast and can make it woody hard. Fibrosis in the region of the shoulder joint or in the axilla can limit the range of movement of the shoulder and this can become painful. Severe fibrosis in the axilla can obstruct the lymph or venous drainage of the arm and cause lymphoedema (a swollen arm). Fibrosis in the region of the brachial plexus can compress the plexus and cause brachial plexus neuropathy with symptoms such as paraesthesiae (e.g. pins and needles), numbness, weakness and pain in the hand and arm. Pulmonary fibrosis visible on a chest X-ray is very common especially in the lung apex, but it rarely causes symptoms. When they do arise, symptoms range from an irritant dry cough to the pneumonia-like symptoms of radiation pneumonitis which generally settle down after a course of corticosteroid therapy.

1.37 Lymphoedema of the arm was a more common side effect in the past when patients were treated by a mastectomy and a full dissection of the lymph nodes in the axilla, especially when this was followed by radiotherapy to the axilla. Axillary surgery undoubtedly
plays an important role in causation. Today axillary radiotherapy is given more selectively and lymphoedema is seen in less than 10% of patients. Lymphoedema may have a vascular element if there is venous compression. Patients with gross lymphoedema are severely handicapped.

1.38 Radiation damage of bone is rare in patients with breast carcinoma. It can occur in the head of the humerus (the shoulder), in ribs and in the clavicle. It is the result of damage to the small arteries which supply the bone resulting in necrosis (tissue death). The damaged bone fractures easily. These fractures are slow to heal and dead bone may ulcerate through the skin. It is rare in the humerus today because the head of the humerus is either not included in the irradiated volume or is shielded during treatment. Rib fractures may be painless and found only on a routine chest X-ray, or can be very painful.

1.39 Brachial plexus neuropathy due to radiotherapy is very rare. It may be due to radiation damage of the nerves or to compression of the nerves by fibrosis in the axilla or lower neck. It has to be distinguished from brachial plexus neuropathy due to injury, surgery or tumour recurrence in the axilla or lower neck.

1.40 Patterns of morbidity in the patients are studied in this report and looked at in the context of their management.

Terms of Reference

2.1 The Royal College of Radiologists invited us to act as an independent team to investigate the complaints made by the members of RAGE following radiotherapy for their breast cancer. To limit the scope of the study it was agreed to confine the study to 15 of the 51 clinical oncology centres in England and Wales and to the RAGE members who were treated at these centres (and who gave their consent to be included) and who were treated during a 14 year period 1980 to 1993. The following were the Terms of Reference:

1 To review the medical records and radiotherapy details of each of the individual patients who have given their written consent.

2 To consult with the clinical oncologists, radiographers, and physicists responsible for their treatments; and to review the treatment facilities where appropriate.

3 If appropriate in order to establish a diagnosis, to offer consultation and examination to individual patients who have reported their symptoms to RAGE.

4 To consider the following issues:
   a) Whether the condition from which the individual patient is suffering is related to the disease process or to previous treatment or both.
   b) Whether there are identifiable factors in the delivery of the radiotherapy, or in its association with surgery and chemotherapy given to the patients, which might have contributed to the development of brachial plexus injury.
   c) What further studies (either audit or research) are needed to resolve the uncertainties relating to the causation of brachial plexus neuropathy.

5 To report to the Board of the Faculty of Clinical Oncology on these issues and their implications for the practice of radiotherapy in the United Kingdom.

6 To produce an anonymised report for publication; this report will be sent to the Department of Health one month before it is published.
The cancer centre visits

Procedure

2.2 An anonymised structured clinical summary has been extracted from the case notes of each of 126 patients who are members of RAGE.

2.3 Two patients had treatment on both sides and separate summaries were made for each treatment. There were thus a total of 128 case records.

2.4 A structured summary has been prepared for each of the 15 cancer centres covering aspects of its working practice and facilities.

2.5 Consultant neurologists have reported on the interpretation of the neurological symptoms of 8 patients who gave their consent to be seen and examined, where the interpretation was in doubt.

2.6 Each clinical summary has been reviewed with a view to determine possible causation.

2.7 The two sets of summaries have been converted into a single computer database.

2.8 We have used the database to identify patterns of care and morbidity that warrant more rigorous investigation and to postulate hypotheses.

2.9 It must be accepted that this report can be no more than a retrospective study as the patients are a self-selected group and valid statistical comparisons cannot be made with a matched group of patients.

2.10 It has been our intention from the start to keep both the names of the patients and the cancer centres visited confidential.

2.11 A confidential summary of the information on each patient has been given to the patient.

2.12 A summary of the information obtained from each cancer centre has been sent to the director of the centre.

2.13 Our inferences, conclusions and recommendations are entirely our own.

Method

3.1 We visited 15 of the 51 cancer centres in England and Wales. They were chosen from a list of centres where members of RAGE had been treated. There is a sensible geographical spread and those chosen include centres which are large and small, and teaching and non-teaching.

3.2 Every cancer centre went to a great deal of trouble to make sure the information we required was available on the days of our visits. Photocopying facilities were made available and we had every help from staff in interpreting medical records where they were not clear. We are extremely grateful for this generous help and appreciate that this entailed extra work for the staff of very busy centres.

3.3 We consulted the medical director of each centre and spoke to as many consultants as seemed reasonable. We also talked to the superintendent radiographer and the radiographer in charge of the planning department, and at least one senior physicist. All of our questions were answered fully and frankly.

3.4 We saw round the centres, including the patients’ waiting areas and the facilities for their comfort and convenience, clinic rooms, the planning and simulation facilities, the physics department, the mould room and the treatment machines.

3.5 We saw patients receiving radiotherapy for their breast carcinoma so that we could understand clearly the methods used for the accurate reproduction of their treatment position at each treatment session.

3.6 We were careful to note the changes that had taken place during the period 1980 to the present time in treatment policy, technique and dose schedule.

3.7 We paid particular attention to Quality Assurance standards in use over this time and the way the consultant/radiographer/physicist team interacted in order to maintain these standards.

3.8 We enquired about the total care of breast cancer patients, including the availability of specialist breast cancer clinics and the nature of collaboration with surgeons, pathologists, radiologists, breast care nurses etc. at both the cancer centre and the peripheral clinics which are held at local District General Hospitals. We asked about the
availability of counselling services, lymphoedema and pain-relief clinics and hospice care.

3.9 We asked about medical/clinical audit meetings, their frequency, attendance and topics and were particularly interested in changes which had resulted from breast cancer audit.

3.10 We enquired about post-graduate in-service training for staff and obtained a general picture of job satisfaction and the morale of the centre.

3.11 We left with useful documents, patient treatment record sheets, photographs of radiotherapy set-up, patient information leaflets, medical audit programmes, and a list of breast cancer publications from the centre.

3.12 The information on the cancer centres was recorded on a data form (Appendix B).

3.13 We gained additional information from recent surveys on breast cancer treatment carried out by the Royal College of Radiologists.

Size and population served by the centre.

3.14 The 15 cancer centres ranged in size from a small centre serving a population 0.5 million to a large centre serving a population of over 3 million.

3.15 The number of patients treated with adjuvant radiotherapy for breast carcinoma ranged from approximately 150 to 800 per year. The total number of breast cancer patients so treated in the 15 cancer centres in 1993 was 6150. In all centres there was an increasing demand for adjuvant radiotherapy over the years 1980 to 1993. The number of patients treated in this 14 year period is conservatively estimated to be 65,000.

Radiotherapy equipment

3.16 Megavoltage equipment. By 1980, all centres had megavoltage machines, cobalt units or linear accelerators. During the years 1980 to 1993 there was an increase in equipment aiming to meet the increasing demand for radiotherapy. Many of the cobalt units have been replaced with linear accelerators and most centres now have a linear accelerator with an electron facility.

3.17 Simulators. By 1993, modern simulation was available in all of the centres but in the early 1980s, 5 centres had no modern simulation. Today 3 centres use computerised tomography (CT) simulation for their breast cancer patients.

3.18 Computer planning of isodose points across the mid-field of the chest wall tangents was available and used routinely in all centres by 1980. A few centres also had isodose plans 5 cm above and below the mid-field level.

Staffing levels

3.19 The review did not attempt to study the adequacy of staff levels. Consultant staffing remains well below the level recommended by the Royal College of Radiologists, but 6 centres we visited had an increase in their number in recent years. Radiotherapy physicist levels have been particularly low but again have improved recently. Radiographer levels were described as low or adequate. No centre claimed that they were unable to treat breast cancer patients adequately because of staff shortages. Several centres had modified their radiotherapy schedules to make better use of staff and machine time.

Management structure

3.20 In the early 1980s few centres had a formal management structure. Today all centres have a formal structure with a clinical director, usually in overall charge of all disciplines, and often within a Group Directorate. Physicists were in a separate directorate in 4 centres. The clinical director in one centre had, we felt, no real authority or responsibility for the smooth running of his department. The larger centres generally had an oncology director with sub-directorates for radiotherapy, medical oncology, haematology, academic oncology, palliative medicine, pain control etc.

Breast cancer management

3.21 In 1980, breast cancer patients were often treated as part of general oncology and specialisation was rare. In recent years, there has been a trend towards breast cancer clinics with experienced specialist surgeons, oncologists and breast care nurses etc. in attendance. Patients seen in peripheral clinics at their local District General Hospital tend to be operated on by a local surgeon with an interest in breast cancer but combined clinics with this surgeon are often not possible for logistic reasons.
3.22 Over the last 5 years, there has been an big increase in the number of specialist breast cancer nurses and counsellors, and every centre and many of the District General Hospitals they serve, now have a breast care nurse available for patients.

3.23 We were impressed with the recent improvements in care of patients in the centres with readily available additional information from nurses and from leaflets, often in other languages where appropriate. All centres now have access to a pain-relief clinic, lymphoedema clinic and palliative care services. None of these services were routinely available in 1980.

Written treatment protocols

3.24 Only 3 centres had written protocols for adjuvant radiotherapy for breast carcinoma in 1980 and most centres used a variety of techniques depending on the consultant looking after the patient. Today, 13 of the 15 centres have formal written protocols and work instructions to meet the varied requirements of patients with operable breast cancer (a good example of one centre’s protocol and work instructions is found in Appendix F) and the remainder have protocols in preparation. Most but not all centres have agreed protocols but others have several variations for different consultants.

3.25 Two centres had a standard policy in 1993 that had not changed since 1980.

Radiotherapy policy for cervico-axillary nodes

3.26 In the early 1980’s the cervico-axillary nodes were commonly treated with radiotherapy but in the last 5 years there has been an increase in axillary surgery and they have been treated in selected high risk patients only. They amount to about 10% of cases only in the majority of centres today.

Policy on patient immobilisation during treatment

3.27 There were many variations in the positions of patients during their radiotherapy and in the means of maintaining and reproducing that position.

Quality Assurance Systems

3.28 According to the World Health Organisation (Geneva 1988), Quality Assurance in Radiotherapy comprises “All those procedures that ensure consistency of the medical prescription and the safe fulfilment of that prescription as regards dose to the target volume, together with minimal dose to normal tissue, minimal exposure of personnel and adequate patient monitoring aimed at determining the end result of treatment”.

3.29 A survey by IPSM of all cobalt units and linear accelerators in the UK led to the discovery of a serious calibration error on a cobalt unit which had resulted in the dose delivered being 25% higher than intended. This incident focussed attention on the adequacy of existing guidance on quality assurance in radiotherapy. In 1991 a working party of the DH’s Standing Medical Advisory Committee (SMAC) recommended that each centre should develop its own QA programme within the framework of a national accreditation scheme such as BS 5750 or ISO 9000.

3.30 A key feature of such a scheme is well-designed documentation. This may be divided into protocols or procedures, which cover a group of generic tasks (e.g. calibrating linear accelerators or a policy for the management of a particular clinical problem) and work instructions which contain quite specific details on how a particular job is to be done. It should be noted that the distinction between procedures and work instructions will sometimes be arbitrary.

3.31 The quality system adopted must be reviewed at appropriate intervals by the management of the radiotherapy service to ensure its continuing suitability and effectiveness. The frequency of such reviews will reflect changes in practice and technology and include assessment of the results of internal quality audits. An essential part of the management review is to establish procedures for corrective action.

3.32 In 1980, these recommendations were, of course, not in place. Nevertheless, several centres already had well established protocols for the treatment of patients with cancer, including breast cancer.

3.33 At the time of our visit, we considered all QA systems were satisfactory or good, and several centres told us that they were working towards BS 5750. One centre had a particularly good programme, an example of their
breast protocol and work instructions are included in Appendix E.

Medical and clinical audit

3.34 Medical audit is recognised as an important aspect of education, both for the trainee and the established career grade specialist. The NHS Management Executive document Working for Patients: Postgraduate and Continuing Medical and Dental Education (1991) indicated that organisational links should be set up and maintained between postgraduate and continuing medical education and medical audit programmes. The Standing Committee on Postgraduate Medical Education (SCOPME) recommends a requirement for all doctors to be contractually obliged to participate in continuing education with formal linking to the educational aspects of medical audit. Participation in audit is a requirement for post FRCR training which should be both of activity and performance within a radiotherapy department.

3.35 All centres were taking part in medical audit programmes, usually within the department itself, sometimes as part of the overall hospital audit. They were commonly held every month, but because of staff shortages it was not always possible for all doctors to be present at each one.

3.36 Most centres held inter-departmental or clinical audit meetings with radiographers, nurses, and physicists. One centre had appointed an audit assistant. Several centres have regular treatment planning meetings.

3.37 Topics discussed at these meetings regarding breast cancer have included the incidence of BPN, shoulder movement, patient satisfaction, prostheses, cosmesis, dose fractionation, deviations from protocol and waiting times for treatment.

Patients’ medical records

4.1 During our visits to the 15 cancer centres, we were able to study the medical records of 123 patients. The records included details of the diagnosis and staging of the extent of the breast cancer, details of surgery and pathology, full details of radiotherapy (including treatment record sheets, physics planning data, planning X-rays and in some cases a photographic record of the treatment positions etc.), concurrent illness and medication, follow up reports and all correspondence. Correspondence included letters to and from their general practitioner, surgeon and other specialists, such as consultants in neurology, orthopaedics, pain relief, dermatology, plastic surgery etc., and in some instances the patients themselves.

4.2 As we were particularly interested to learn about the most recently treated members of RAGE, we also saw the medical records of 3 additional patients who gave their consent and who were treated in 1993 at two other cancer centres which we did not visit. The total number of patients in the review is 126.

4.3 In 30 cases the records were incomplete, patients having moved home or continued follow up care with their surgeon or another consultant at a different hospital, or with their general practitioner. This missing information was obtained for all but 2 patients.

4.4 We also had important information written by the patients on their consent forms, describing their symptoms.

4.5 Data was extracted onto a data form (Appendix A).

4.6 We used all of this information in reaching our conclusions.

RAGE reports

4.7 Two valuable reports produced by RAGE, Consequences and symptoms of radiation damage and Analysis of the replies to a RAGE questionnaire, are reproduced as Appendix C and D.

Preliminary publications studied

4.8 A literature search on brachial plexus neuropathy was carried out. This was helped greatly by the references included in the earlier report of the Maher Com
5 Patients’ medical records

Comments on the medical records

5.1 During the period 1980 to the end of 1993, 249 members of RAGE were treated in the 15 cancer centres. Written consent for inclusion in the review was obtained from 123 members. Their medical records together with those of 3 other patients treated in 1993 in 2 other centres were studied (total 126).

5.2 In general the quality of the medical records was good and in no case were we unable to determine how the patient had been treated. Follow up records were understandably not complete in all cases, but this was overcome by correspondence with General Practitioners and others. This was successful in all but 2 cases.

5.3 A major concern of RAGE was that all too often they were repeatedly reassured that their symptoms were unrelated to their radiotherapy and put down to carpal tunnel syndrome and frozen shoulder. Whilst both of these diagnoses were reasonable in the first instance and needed to be excluded, there is evidence in the follow up records of a minority of patients, written by both clinical oncologists and surgeons, that symptoms were seriously undervalued.

Age, sex and menopausal status of patients

5.4 There were 125 female patients and 1 male patient.

5.5 Their ages at the time of treatment ranged from 25 to 81 years. Their age distribution is unremarkable and is shown in Chart 1.

5.6 Menopausal status was not recorded in 20 female patients, of the remainder, 33 were premenopausal, 7 peri-menopausal and 65 postmenopausal.
Brachial plexus neuropathy

Incidence

5.8 Our criteria for the diagnosis of brachial plexus neuropathy included a firm diagnosis by a consultant neurologist, orthopaedic surgeon or pain relief specialist, and the pattern of motor and/or sensory symptoms and physical signs in the arm and/or hand with or without pain.

5.9 We were able to identify brachial plexus neuropathy (BPN) in 55 instances (54 patients) in the 126 patients. In 9 it was considered to be due to tumour recurrence in the region of the plexus and in 2 cases it was obviously due to axillary surgery (in patients who received no radiotherapy on the side of the neuropathy). One patient who had symptoms suggestive of BPN died of advanced disease without evidence of local recurrence and she has been included as a case of brachial plexus due to radiotherapy. Thus, 44 patients were believed, suffered from damage of their brachial plexus due to radiotherapy (BPN/RT) and in one case this was bilateral. In addition there were 11 patients who were free...
Brachial Plexus Neuropathy following Radiotherapy

From tumour recurrence and where the diagnosis of BPN was uncertain.

5.10 Where patients developed BPN following radical axillary surgery and radiotherapy (2 cases), the cause of BPN was assumed to be due to the radiotherapy for the purpose of the analysis. We accept that surgery may well have been a cause.

5.11 Where patients developed BPN and the first symptom was reported to have arisen during the course of radiotherapy (2 cases), the cause of BPN was assumed to be due to the radiotherapy for the purpose of the analysis. It is possible that the symptoms might have been caused by a stretch injury of the nerve roots during the treatment planning session, especially as the head was turned to the opposite side and the arm strained to a right angle. Cervical spondylitis (arthritis in the neck) accounted for the arm symptoms in 2 patients who developed symptoms before radiotherapy.

5.12 Where patients with BPN developed tumour recurrence in the axilla or lower neck adjacent to the plexus, it was assumed that the BPN was due to tumour. We accept that it might have been due to the radiotherapy or to a combination of the two.

5.13 The 11 patients who were free from tumour recurrence and where the diagnosis of BPN was uncertain were invited to be examined by an independent consultant neurologist. Consent to this was given by 8 of them: brachial plexus neuropathy due to radiotherapy was diagnosed in 4 of them, making a total of 48 cases of BPN/RT; 3 cases were thought not to have BPN and one remains a possibility. The 3 patients who declined to be examined remain as possible cases.

![Chart 2: BPN status and cause by year of treatment (see also Table 1)](image)
5.14 We have agreed that 48 patients have BPN/RT i.e. 38% of the patients in the review. One of these patients had bilateral BPN/RT making a total of 49 instances of BPN/RT. A firm diagnosis of BPN/RT had already been made by a consultant in neurology, orthopaedics or pain relief in 29 of these cases.

5.15 The incidence of BPN/RT by year is shown in Chart 2 and Table 1. In the first 7 years in the review (1980-86) there were 66 patients and 41 cases of BPN/RT (62%). In the second 7 years (1987-93) there were 60 patients and only 7 cases of BPN/RT (12%). Of the 60, 8 were treated in 1993: 4 did not have BPN; 1 had BPN/RT, 1 BPN due to tumour and 1 BPN due to surgery; in 1 case the diagnosis was uncertain.

5.16 Three of the cancer centres visited had no confirmed case of BPN/RT among the patients’ notes we reviewed.

5.17 The time to the onset of the first symptom of BPN/RT ranged from before completion of radiotherapy to 10 years after radiotherapy. The spread of time of onset of the first symptom is shown in Table 2 (p. 18). By 27 months over half of the patients with confirmed BPN/RT had developed symptoms.

5.18 Prior (neo-adjuvant) cytotoxic chemotherapy had been given in 3 cases and the intervals between finishing chemotherapy and starting radiotherapy was over 2 weeks in each case.

5.19 Sensory symptoms in the hand were the most common first symptoms and included “pins and needles” and/or numbness, often in the thumb and first finger. Pain in the shoulder was a less common first symptom. Patients went on to develop a combination of upper limb symptoms. Most patients developed muscle weakness in the hand or arm and 23 (48%) went on to develop a flail wasted useless arm. Pain was a major feature in 34 patients and often very difficult to control. In 3 patients pain was of late onset and of only moderate severity; their paraesthesiae were more distressing than their pain. Four patients with BPN/RT had no pain. Both sensory and motor changes were present in 28 patients. There were mainly sensory changes in another 13, and mainly motor in 4 patients. The presence of Horner’s syndrome was not found.

5.20 Radiation reactions are said to be exacerbated in collagen vascular diseases. One patient with systemic lupus erythematosus (SLE) developed a possible BPN/RT. Another 2 patients developed generalised scleroderma soon after radiotherapy and had very severe acute radiation reactions.

5.21 The majority of patients also had other radiotherapy morbidity (Table 3).

5.22 Treatment of BPN/RT was largely ineffective and improvements tended to be of temporary duration. In most cases BPN/RT was progressive, becoming more severe with time. Treatment included physiotherapy, analgesic drugs including regular strong opiates, nerve blocks, acupuncture, TENS machines and brachial plexus decompression. In no case did surgical decompression give lasting or complete relief of all symptoms.

### Table 3: Incidence (no.) of treatment related morbidity in the 126 RAGE patients in the review

<table>
<thead>
<tr>
<th>Condition</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPN</td>
<td>48</td>
</tr>
<tr>
<td>Skin</td>
<td>10</td>
</tr>
<tr>
<td>S/C fibrosis</td>
<td>27</td>
</tr>
<tr>
<td>Bone necrosis</td>
<td>8</td>
</tr>
<tr>
<td>Lung fibrosis</td>
<td>10</td>
</tr>
<tr>
<td>Oedema</td>
<td>22</td>
</tr>
<tr>
<td>Shoulder stiffness</td>
<td>21</td>
</tr>
<tr>
<td>Skin</td>
<td>28</td>
</tr>
<tr>
<td>S/C fibrosis</td>
<td>20</td>
</tr>
<tr>
<td>Bone necrosis</td>
<td>14</td>
</tr>
<tr>
<td>Lung fibrosis</td>
<td>16</td>
</tr>
<tr>
<td>Oedema</td>
<td>11</td>
</tr>
<tr>
<td>Shoulder stiffness</td>
<td>14</td>
</tr>
<tr>
<td>Bone necrosis</td>
<td>7</td>
</tr>
<tr>
<td>Lung fibrosis</td>
<td>8</td>
</tr>
<tr>
<td>Oedema</td>
<td>12</td>
</tr>
<tr>
<td>Shoulder stiffness</td>
<td>28</td>
</tr>
<tr>
<td>Lung fibrosis</td>
<td>7</td>
</tr>
<tr>
<td>Oedema</td>
<td>12</td>
</tr>
<tr>
<td>Shoulder stiffness</td>
<td>27</td>
</tr>
<tr>
<td>Lung fibrosis</td>
<td>8</td>
</tr>
<tr>
<td>Oedema</td>
<td>13</td>
</tr>
<tr>
<td>Shoulder stiffness</td>
<td>46</td>
</tr>
</tbody>
</table>

Brachial plexus neuropathy due to radiotherapy (BPN/RT)
Brachial plexus neuropathy due to tumour

5.23 BPN due to tumour was identified in 9 patients, 8 had known cervico-axillary recurrence and one had extensive metastatic disease and suspected axillary recurrence and had not received any cervico-axillary radiotherapy.

5.24 Paralysis of the arm and/or hand was a predominant feature. Pain was a major symptom in 6 of the 9 patients. Horner’s syndrome was present in one case. Two patients have died of malignant disease.

Brachial plexus neuropathy due to surgery

5.25 In the two cases of BPN due to surgery, symptoms of pain in the axilla and painful stiffness of the shoulder came on immediately after an axillary dissection and progressed to severe pain, paraesthesiae and weakness in the arm. The brachial plexus received no radiotherapy in either of these patients.

Other radiation morbidity

Severe subcutaneous fibrosis

5.26 Out of the total 126 cases reviewed, 58 are recorded as having severe post-radiotherapy fibrosis (46%). This was evident in the irradiated breast as a hard contracted deformed breast, and in the cervico-axillary region as a mass or as woody thickening, often in the region just below or just above the clavicle or in the axillary folds where it often tethered the shoulder, limiting movement. It was also seen as a thickened narrow strip of tissue at the site of overlap of the chest wall and the cervico-axillary fields (drawn in the notes as in Fig. 3).

5.27 Severe subcutaneous fibrosis was recorded in 27 of the 48 patients with BPN/RT (56%). In one patient axillary fibrosis was so severe that it interfered with the arterial blood supply of the arm and her arm had to be amputated because of the risk of gangrene.

Radionecrosis of bone

5.28 Bone necrosis was recorded in 18 patients (14%). A radionecrotic fracture of the clavicle, ribs or scapula (shoulder blade) was seen in 15 of these cases. The fractures were all painful and slow to heal and one patient had to have repeated surgical removal of dead bone.

5.29 Bone necrosis was frequently associated with severe subcutaneous fibrosis (Table 4, p24) and was present in 8 cases with BPN/RT (17%).

Lymphoedema of the arm

5.30 Lymphoedema of the arm was recorded in 46 patients (36%) and was present in 22 patients with BPN/RT (48%) and 27 patients with chronic stiffness of the shoulder (53%).

Shoulder stiffness

5.31 Shoulder stiffness was the commonest symptom and was recorded in 51 patients (40%), and was an early symptom in 21 of the patients with BPN/RT. It improved with physiotherapy in many instances.

Skin changes

5.32 Skin changes were recorded in 28 patients (22%). In most patients it referred to telangiectasia and dys-pigmentation at the site of the boost dose of radiotherapy to the tumour bed or scar. In 4 patients a radionecrotic ulcer developed and 2 of these patients also had BPN/RT.

Lung fibrosis

5.33 Lung fibrosis was recorded in 29 patients. In most patients it was a symptomless X-ray finding. In 4 patients it was associated with chronic shortness of breath and occasionally with radiation pneumonitis which usually settled with corticosteroid treatment.

Other suffering

5.34 Morbidity that we have not been able to quantify include the deep emotional distress caused by the side effects of treatment, sometimes by the breakdown of the doctor patient relationship, by loss of function (including a singing voice) and by loss of a job.
Methods of treatment used

Surgery

6.1 The majority of patients (42) had only a local excision of their breast carcinoma. Local excision plus a biopsy or removal of the lower axillary nodes was performed in 38, and a more extensive axillary dissection in 14 patients. A simple mastectomy was performed in 27 and a radical or Patey mastectomy in 5 patients. It appeared that 8 patients had a full axillary clearance but this was not always clearly defined.

Radiotherapy techniques (Table 4)

Chest wall tangents only

6.2 The chest wall only was irradiated by tangential fields in 26 patients, 11 of which had an additional boost to the site of the tumour. Two patients treated with unusually long wedged tangents and a boost developed BPN/RT. BPN due to tumour was identified in 2 patients and BPN due to surgery in 2 (one of these patients had tangential radiotherapy to the other breast only).

Large anterior cervico-axillary (CA) nodes field and chest wall tangents (Fig. 4a)

6.3 Large CA fields are defined as being longer than 17 cm. This technique was used for 17 patients, 1 developed BPN/RT, 3 cases had possible BPN, 2 had BPN due to recurrent tumour and 11 had no BPN.

Small anterior supraclavicular (SC) field and chest wall tangents (Fig. 4b)

6.4 This technique used tangents which included the lower axilla and a small supraclavicular field, defined as less than 12 cm. in length. This technique was used for 33 patients, 26 developed BPN/RT, and 2 patients developed BPN due to tumour; 5 did not develop BPN.

Large anterior and posterior CA fields and chest wall tangents.

6.5 This technique was used for 15 patients. BPN was found in 11 cases, 10 due to radiotherapy, and one to tumour; 3 cases did not have BPN and 1 remains a possibility.

Large anterior and small posterior CA fields and chest wall tangents (Figs. 4c and 4d)

6.6 This technique was used for 28 patients, 8 developed BPN/RT and 2 had possible BPN/RT; 18 were thought not to have BPN.

Deep x-ray technique

6.7 Three patients were treated by this technique and none developed BPN/RT. BPN due to tumour developed in one patient.

Other techniques

6.8 Only the internal mammary chain of nodes (nodes lying under the front ends of ribs) was irradiated in one patient and only the scar in another. BPN due to tumour developed in one of them. Additionally, 2 patients received treatment to the cervico-axillary chain using varying techniques including large anterior fields followed by boosts with small anterior and posterior fields, BPN/RT occurring in one of them.

Treatment planning

Planning and simulation

6.9 Pre-treatment planning was carried out in all cases by the clinical oncologist, planning radiographer and physics team.

6.10 It included decisions regarding the positions of the patient during treatment so that positions could be reproduced easily by the radiographers at each treatment session.

6.11 The position, size and angles etc. of the chest wall tangents and the cervico-axillary or supraclavicular fields were determined and the patient marked accordingly, often with tiny tattoo marks, and measurements taken.

6.12 In all cases, an outline was taken of the chest wall in the treatment position and an isodose plan of the % dose distribution from the chest wall tangents was prepared by the physicists (Appendix G). In a very few patients isodose plans were prepared for the nodal regions.

6.13 X-rays (or ultra-sound) were used in most cases
to identify and minimise the depth of lung included in the treated volume. X-rays were also used to determine the position of lung and shoulder shielding where necessary.

6.14 Dose and dose schedules were prescribed for each volume. Cancer centres differed in the prescription points chosen. Only one cancer centre routinely modified the dose delivered to the chest wall with a lung-correction factor.

**Field overlap policy**

6.15 Cancer centres, and sometimes individual consultants within the centre, had different policies regarding the gap to be left between the upper edge of the beam of the chest wall tangents and the lower edge of the beam of the anterior cervico-axillary or supraclavicular fields. The gap also depended on the divergence of the beams from the different radiotherapy machines. The gap size ranged from no gap to 2 cm. In the recent years some centres have avoided overlap at this field junction by other methods such as couch rotation or blocking the beams. New linear accelerators with asymmetric jaws will make this easier.

**Posterior axillary fields**

6.16 There was variation in the use of a posterior axillary field. In the majority, a small posterior field was used to bring the dose of the mid-axilla up to the same level as the dose received by the lymph nodes above the clavicle from the anterior field. The posterior field was either
parallel and opposite to the outer half of the anterior field, or angled in line with the slope of the axilla (Figs. 4c and 4d). The position was sometimes planned with the use of X-rays but more often planned by eye.

6.17 Very occasionally a boost dose was given to the base of the axilla concurrent with the boost to the tumour bed or scar (Fig. 5).

**Radiotherapy machines used**

6.18 All of the cancer centres had modern megavoltage machines by 1980, i.e. cobalt units or linear accelerators. By 1993, deep X-ray machines were still used very occasionally for treatment of breast cancer patients in 2 cancer centres.

6.19 Boost doses to the tumour bed or scar were generally given with external beam radiotherapy using electrons, cobalt teletherapy or deep X-rays. A minority had iridium wire implants.

**Patient position during treatment**

6.20 There were considerable differences in the positions in which patients were treated between the cancer centres.

6.21 In the earlier years, many centres treated the tangents with the patient in a semi-supine position with the arm raised above the head. The patient then moved to lie supine with the arm down so that the cervico-axillary chain of nodes could be treated. We called this “moderate” movement. Two centres treated the chest wall with the patients lying on their back with their arm up and the nodes with patients lying on their side with the arm down by their side. We called this “major” movement.

6.22 More recently, practically all centres have treated their patients in a static position with the aid of a single or double arm pole (Appendix H) and an angled breast board or firm wedged pillows.

6.23 Most centres treat with the patient’s head turned to the opposite side. A few centres treat with the head facing straight forward.

6.24 Thirteen different policies in the 15 cancer centres over the 14 years, were identified. These are described in Appendix E.

6.25 The review suggests that movement of the patient, leading to a change in the position of the arm, between the treatment of the chest wall and the nodes increases
Radiotherapy dose schedules

6.27 The biological effects of radiotherapy depend not only on the total dose received by the tissues from a course of treatment, but also on the total number of individual treatments (called fractions), the size of the individual fractions, the intervals between the fractions (i.e. the number of fractions per week) and the overall treatment time. It is also relevant whether all fields are treated at each treatment session. The following list of individual parameters must be viewed in this light.

Total dose of radiotherapy

6.28 The total dose prescribed for daily treatment of the CA chain was similar in the patients who developed BPN/RT and those who did not. It ranged from 42.5 Gy to 61.6 Gy (mean 50.8 Gy) in patients who developed BPN/RT and from 40 Gy to 58 Gy (mean 47.7 Gy) in patients who did not develop BPN/RT.

6.29 The total dose prescribed for treatment of the CA chain delivered in 5 fractions per fortnight was similar in the patients who developed BPN/RT and those who did not. It ranged from 42 Gy to 51 Gy (mean 47 Gy) in patients who developed BPN/RT and from 40 Gy to 53 Gy (mean 48 Gy) in patients who did not develop BPN/RT.

the likelihood of BPN/RT significantly. It appears that the greater the movement the greater the likelihood of BPN/RT (Table 5).

6.26 If we omit patients treated with tangents only (26) and the other cases where treatment was to the internal mammary (IM) chain or scar only (2) and include only those patients treated with chest wall and CA fields where movement had some meaning, there were a total of 98 patients. Of 47 patients where movement between fields was apparent, 34 developed BPN/RT (72%).

<table>
<thead>
<tr>
<th>Table 5: BPN status and cause by presence/absence and extent of patient movement. (98 of the patients had both the CA nodes and the chest wall treated.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPN status and cause</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>BPN/RT</td>
</tr>
<tr>
<td>Possible BPN/RT</td>
</tr>
<tr>
<td>BPN surgery</td>
</tr>
<tr>
<td>BPN/tumour</td>
</tr>
<tr>
<td>No BPN</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>BPN/RT as % of total</td>
</tr>
</tbody>
</table>

Brachial Plexus Neuropathy following Radiotherapy
Table 6: BPN status and cause by frequency of treatment, patients

<table>
<thead>
<tr>
<th>BPN status and cause</th>
<th>Frequency of treatment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily</td>
<td>5 fractions per fortnight</td>
</tr>
<tr>
<td>BPN/RT</td>
<td>28</td>
<td>18</td>
</tr>
<tr>
<td>Possibly</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>BPN/Tumour</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>BPN/surgery</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>No BPN</td>
<td>38</td>
<td>13</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>75</td>
<td>33</td>
</tr>
<tr>
<td><strong>BPN/RT as % of total</strong></td>
<td>37</td>
<td>55</td>
</tr>
</tbody>
</table>

Number of treatments per week (Table 6)

6.30 The majority of patients (75) were treated daily, i.e. 5 times per week on Monday to Friday; 33 were treated 5 times per fortnight, i.e. Monday, Wednesday, Friday, Tuesday, Thursday; and 13 patients were treated 3 times per week on Monday, Wednesday and Friday. The remaining 5 patients were treated with a variety of fractions, including once per week.

6.31 BPN/RT was identified in 28 patients who were treated daily (37%), 18 patients who received 5 fractions per fortnight (55%), 1 patient who received 3 fractions per week (8%) and 1 other patient (who was treated on Monday, Tuesday and Thursday).

Overall treatment time

6.32 The total treatment time was similar for patients who developed BPN/RT and for those who did not. This ranged from individual extremes of 20 to 100 days (mean 36 days) for patients who developed BPN/RT and 14 to 54 days (mean 30 days) for patients who did not.

Fraction size

6.33 The size of the fractions prescribed for the cervico-axillary chain were similar in the patients who developed BPN/RT and those who did not. They ranged from 5 Gy to 1.6 Gy (mean 2.64 Gy) in patients who developed BPN/RT and 5 Gy to 2 Gy (mean 3.14 Gy) in patients who did not.

Additional axillary boost dose

6.34 Four patients received a boost dose to the base of the axilla and 3 developed BPN/RT.

Were all cervico-axillary fields treated every time?

6.35 On 4 occasions the posterior axillary field was not treated at each treatment session and was treated in only 2 – 4 fractions. BPN/RT developed in 2 cases and severe fibrosis in the posterior axillary fold was noted in the others.
Limitations of the review

7.1 The incidence of BPN/RT in patients treated for operable breast cancer in the United Kingdom is unknown. Clinical oncologists believe it is very rare. The patients in this review are a self-selected group and it is likely that there are more patients with BPN/RT who have not joined RAGE. The patients included in this review were also selected as they are a small sample of the total membership, and self-selected in that they are a group who gave their consent for inclusion in the study when many did not. We have identified 48 RAGE members with BPN/RT from the 15 cancer centres treated over a 14 year period, out of a conservative estimate of 65,000 breast cancer patients treated at these centres in this period.

7.2 The data collected is selected data, and we have not had the opportunity to compare it with that of matched patients who are not members of RAGE. The review must, therefore, be seen only as a retrospective study and not as a study based on a randomised sample.

To cure or not to cure?

7.3 A relatively high dose of radiotherapy is needed to prevent a local recurrence in breast cancer patients and some clinical oncologists believe that an even larger dose is necessary if radiotherapy is to improve the chance of cure in some patients. Whilst patients do vary in their response to radiotherapy (just as people vary in their response to sunburn), the greater the dose of radiotherapy the greater the chance of normal tissue damage. Uncertainty remains about the precise role of radiotherapy in relation to cure and it is understandable that there are those who treat with a dose close to the tolerance of the normal tissues with a greater risk of unwanted side effects, and those who use a lower “safer” dose.

Individual sensitivity to radiotherapy

7.4 Some patients are unusually sensitive to radiotherapy and this may be genetic. When we are able to determine accurately which patients are unusually sensitive, doses can be individually tailored for them. This time has not yet come but may not be far off. However it must be remembered that decreasing the dose may be associated with an increased risk of tumour recurrence.

7.5 In our opinion, some of the patients whom we have identified as suffering from BPN/RT and other serious radiation morbidity were not unusually sensitive to radiotherapy, as they had only modest damage of the other irradiated tissues. We believe that there may be technical reasons why some patients developed serious side effects and that it may be possible to reduce the number of patients who suffer unnecessarily.

Radiotherapy dose

7.6 If BPN/RT is not due to patient sensitivity, then it is likely to be due to the dose received by the brachial plexus and the adjacent tissues. The biological effects of a course of radiotherapy depend, as previously stated, on the total dose, the number and size of the individual fractions, their scheduling, and the overall total time taken for the course of radiotherapy. Most of our understanding is in the tumour and normal tissue effects of conventional radiotherapy delivered in daily fractions (5 fractions per week).

7.7 When radiotherapy is delivered in fewer larger fractions over the same time, the total dose has to be reduced appropriately in order to achieve the same effect. In this situation there is less latitude in the choice of dose which will control the tumour without damaging the patient. Over the last thirty years work has been carried out on the safe use of three and two fractions per week. One fraction per week has been disappointing in curative radiotherapy but is useful in palliation. Radiobiological formulae have been devised to determine iso-effective doses but although the more recent formulae are more accurate, they do not cover the range of dose schedules used for the patients in this review.

7.8 Analysis of both fraction size and total dose prescribed showed a similarity in the patients with and those without BPN/RT.

7.9 Analysis of method of dose scheduling (Table 6, p. 26) showed a higher proportion of BPN/RT in those treated in 5 fractions per fortnight. Of these, 18 of 33 developed BPN/RT (55%). Of the patients treated in daily fractions, 28 of 75 developed BPN/RT (37%). Of the patients treated in 3 fractions per week, 1 of 13 developed BPN/RT (8%).

7.10 The relatively “high dose” techniques aiming for cure (with doses close to normal tissue tolerance) were identified in 36 patients. In our opinion, the doses which
fall into this category are (i) long courses of 5-6 weeks delivering 60 Gy or more in daily fractions; (ii) long courses of 5-6 weeks delivering 47 Gy or more in 5 fractions per fortnight; and (iii) short courses of 3 weeks duration delivering 40 Gy or more in 5 fractions per fortnight. BPN/RT developed in 25 of these 36 patients (69%); there was also one case of possible BPN/RT.

7.11 It must be pointed out that these dose factors must be looked at alongside other factors which may be more important.

**Accuracy of delivery of radiotherapy**

7.12 Another factor which influences the effect of radiotherapy is the accuracy of delivery of the dose prescribed. Errors can be made in the calculation of dose and the entry of dose into the control panel of the treatment machine. All doses for the patients were re-checked by the physicists. On the basis of this evidence we are satisfied that no errors were found in dose calculation or in delivery. Quality Assurance in all centres was adequate and improving as rapidly as staffing levels would permit towards the very high standards required today.

**Effect of additional dose**

7.13 Another factor is an increase in dose above the prescribed dose to the brachial plexus due to overlapping of radiation fields.

7.14 The most obvious factor noted in this review was the association of BPN/RT with movement of the patient between the treatment of the chest wall and the nodes (Table 5, page 25). 33 of 47 (74%) patients who were moved developed BPN/RT while only 3 did so out of 20 (15%) patients who were not moved. There were a further 31 patients for whom the presence or absence of movement was unknown: 9 (29%) developed BPN/RT.

7.15 Movement was identified as “major” in 12 cases where the whole body and the arm were moved into completely different positions between treatment of the chest wall and the nodes. All of these patients developed BPN/RT (100%). Movement was identified as “moderate” in 35 cases where the arm was moved from above the head, hand on forehead and elbow forward to a hand-on-hip type of position (Fig. 6). BPN/RT developed in 22 patients (63%).

7.16 The dose received by all or part the brachial plexus in either of these situations is not known. Many clinical oncologists did not routinely record the maximum dose received within the cervico-axillary volume from the prescribed dose delivered by anterior and posterior fields.

7.17 These “high dose” techniques described in 7.9, coupled with “moderate” movement of the patient, were associated with BPN/RT in 21 patients out of 23 (91%), 7 with the daily fraction regime and 14 with the 5 fraction per fortnight regime. Both patients who did not develop BPN/RT had very severe bone necrosis.

7.18 Four patients had a boost of 9 or 10 Gy in 3 to 5 fractions to the base of the axilla and 3 of them developed BPN/RT.

7.19 We were unable to identify with certainty the patients who could be considered unusually sensitive to radiotherapy.

7.20 It was not possible to calculate the dose received by the brachial plexus from long chest wall tangents because an outline and isodose plan was only provided for mid-field. Some centres took an outline 5 cm above and below the mid-field but this did not include the axilla. It was also not possible to know if a boost dose to a tumour bed or scar in the upper outer quadrant of the breast contributed to the brachial plexus dose except in one case where there was gross puckering in the axilla.

7.21 There was an unusually high incidence of lymphoedema of the arm (36%) and this was often severe. The reason for this is likely to be related to dose and movement between fields.

7.21 Gross distortion of the breast due to post-radiation fibrosis appeared to be associated with failure to treat both tangents on the same day and alternating wedged and open tangents. Similarly gross fibrosis of the posterior axillary fold appeared to be associated with hypofractionation of the post axillary field during the course of radiotherapy. The one patient who was treated in one fraction per week developed extremely severe fibrosis of the breast and chest wall (the nodes were not treated).
8.1 This review is of necessity based on an unrandomised sample and our recommendations must therefore be treated with caution. They relate to both modern practice and future research.

8.2 The data suggests that brachial plexus damage due to radiotherapy affects a small minority of patients receiving radiotherapy for breast cancer and that the incidence of this problem is declining.

8.3 Brachial plexus neuropathy is a particularly distressing condition which can lead in some patients to the development of a flail and useless arm and pain which can be very difficult or impossible to control. Modern treatment of brachial plexus neuropathy is often ineffective and therefore prevention is extremely important.

8.4 Our recommendations as to modern practice relate to:

- **patient selection** para 8.5
- **the patients’ position** 8.6 – 8.7
- **dosimetry** 8.8 – 8.14
- **protocols** 8.15
- **organisation** 8.16
- and the need to recognise BPN 8.17 – 8.19

Our research proposals relate to the dose to the brachial plexus, the relevance of “high dose” techniques, optimum radiotherapy dose schedules and genetics (8.20 and Box A).

### Modern practice

#### Patient selection

8.5 In our present state of knowledge, and in our opinion, patients should be given cervico-axillary radiotherapy selectively and not treated routinely.

#### Patients’ position during radiotherapy

8.6 We believe that it is essential that patients needing cervico-axillary radiotherapy should be treated throughout in a static position. It is especially important that when chest wall tangents are also used the patient remains in this static position.

8.7 We were impressed with the double arm pole used with the head straight and thought that this position was more readily reproducible and put less strain on the roots of the brachial plexus both during treatment planning and during treatment (Appendix H).

### Dosimetry

8.8 On the evidence of the review, we are unable to advise on optimum dose and dose fractionation techniques. Published evidence suggests that for a 5 fractions per fortnight technique, when a total dose has been selected with the use of a Nominal Standard Dose (N.S.D.) or related formula, there is a higher than usual incidence of BPN/RT [1]. Further results with the lower total dose known to be recommended today are needed to confirm that this technique is safe and effective, especially as it is more convenient for patients, than a lengthy course of daily treatment.

8.9 We advise caution with the “high dose” techniques (i.e. (i) long courses of 5-6 weeks delivering 60 Gy or more in daily fractions; (ii) long courses of 5-6 weeks delivering 47 Gy or more in 5 fractions per fortnight; and (iii) short courses of 3 weeks duration delivering 40 Gy or more in 5 fractions per fortnight). In our opinion these “high dose” techniques appear, in this review, to be associated with a greater risk of BPN/RT than the more usual lower dose schedules.

8.10 We recommend that any one fraction per week technique is inadvisable because of poor tumour control and high morbidity. This is supported by the literature [2, 3].

8.11 We recommend that all fields, except the boost to the tumour bed or scar, be treated at each treatment session, including wedged and open tangents. This is especially important in hypofractionation techniques.

8.12 We advise against the use of an additional boost to the base of the axilla.

8.13 Dosimetry of the axilla needs closer attention than it receives routinely today, with greater involvement of the physicists. In every case the maximum dose which might be received by the cervico-axillary tissues should be recorded on the treatment sheet for audit purposes.

8.14 We advise caution in patients with collagen vascular diseases such as scleroderma, systemic lupus...
erythematous and rheumatoid arthritis because these patients may have unusually severe early and late radiations reactions [4].

**Protocols for breast cancer management**

8.15 All cancer centres should have an agreed written Protocol for breast cancer management which is subject to audit and reviewed regularly, so that advances and initiatives are not inhibited. For the same reason we cannot advocate a single national protocol in the present state of knowledge.

**Organisation of breast cancer treatment**

8.16 We agree with others that where possible patients should be cared for by a multi-disciplinary team of breast specialists with a wide knowledge of the disease. The team should include a nurse and have access to counsellors, pain relief and lymphoedema clinics etc. Information on diagnosis, treatment, side effects and prognosis etc. should be readily available and supplemented by written information in a language which the patient can understand.

**Recognition of relationship of breast cancer and brachial plexus neuropathy**

8.17 Surgeons and oncologists need to be more aware of the brachial plexus syndromes that can arise in breast cancer patients, their causes and management. The Maher Report will have gone a long way to achieve this.

8.18 We support the view that only surgeons with experience in the field should attempt decompression of the brachial plexus.

8.19 Patients need acknowledgement of, and, when possible, an explanation of, their symptoms, whether or not these are thought to be due to their cancer or its treatment. These symptoms need to be recorded in the medical records and taken into account in the audit procedures in the centre.

**Research**

8.20 Recognising the limitations of an analysis based on a small self selected group of patients, we have identified the need for the research studies set out in Box A which would throw further light on our findings and might substantiate our recommendations. Some of this research is already under way.

**References**


Box A: Research proposals

1  The dose to the brachial plexus

*Hypothesis: the brachial plexus may receive a greater dose than intended due to field overlap if the position of the patient is changed during treatment of the cervico-axillary nodes and the chest wall, especially when tangents are used.*

Studies are needed of the variation in the anatomy of the axilla and in the positions of the brachial plexus during different movements of the arm and head, and their relationship to the customary bone landmarks and the skin marks used by clinical oncologists to define radiotherapy field limits.

This would require a collaboration between a clinical oncologist, a clinical radiologist, a physicist, a neurologist and an anatomist.

2  The use of high dose techniques

*Hypothesis: a relatively high dose schedule of radiotherapy improves the survival prospects of some patients with early breast cancer.*

Large scale survival studies are needed to show whether or not a relatively high dose of radiotherapy improves the survival prospects of identifiable patients with operable breast cancer. These studies are in progress. If this cannot be proven, lower “safer” doses should be used to control local disease.

3  Dose fractionation technique

*Problem: British clinical oncologists use a range of different dose fractionation techniques for adjuvant radiotherapy for early breast cancer. The optimum dose fractionation technique is not known.*

Multi-centre studies of dose fractionation are needed to determine the optimum treatment for operable breast carcinoma. For example, comparisons could be made between the efficacy of delivering the appropriate total dose in a short time (i.e. 3 weeks) versus a longer overall time (i.e. 5 weeks) and between the use of daily fractions and 5 fractions per fortnight over the same overall time (i.e. 5 or 6 weeks). Both studies could be carried out by the Royal College of Radiologists but would need funding.

Patients would need to be treated in a static position if chest wall tangents and cervico-axillary fields are used, with all fields treated at each session. There would need to be agreement on the dose prescription points and the inter-treatment intervals. The studies would need to use end points of local recurrence and survival and uniformly measured normal tissue morbidity measured at standard intervals after treatment.

This study would undoubtedly include some patients receiving neoadjuvant cytotoxic chemotherapy which may influence survival. Additional information could be obtained on their interaction and the subsequent normal tissue morbidity, including BPN, which we have been unable to assess in this review.

4  Genetics

*Problem: patients vary in their sensitivity to radiotherapy; the reasons for this are not understood at the present time.*

Genetic studies of the variations in patient radiosensitivity are in progress.
Abduction of the arm movement outwards away from the body
Axilla the armpit
Brachial plexus the nerves to the arm
Boost dose an additional dose of radiotherapy to a site with a high risk of tumour recurrence
Carpal tunnel syndrome pain and paraesthesiae in the hand due to pressure on nerves at the wrist
Clavicle the collar bone
Cellulitis infection often in a swollen arm
Cervical the neck
Cervico-axillary nodes the lymph nodes in the lower neck and axilla which drain the arm and breast
Cervical spondylitis arthritis in the neck
Clinical oncologist a non-surgical cancer specialist
Clinical radiologist a diagnostic radiologist
Cobalt Unit megavoltage radiotherapy machine
Decompression surgical relief of pressure (of the brachial plexus)
Dyspigmentation altered skin pigmentation, such as follows a burn
Dose of radiotherapy the unit of dose of radiotherapy is the Grey (Gy)
Electron therapy superficial beam of radiotherapy that can be used to treat surface tissues, eg a boost to the tumour bed
Fibrosis scarring
Flail arm paralysed floppy arm
Fraction an individual dose of radiotherapy as part of a course of treatment
Fractionation the techniques of scheduling fractions in a course of radiotherapy
Frozen shoulder a painful stiff shoulder of uncertain cause
Horner’s syndrome signs caused by pressure on nerves in the neck which include drooping of the eyelid and a small fixed pupil.
Humerus the bone of the upper arm
Hypofractionation individual treatments of radiotherapy course used in a schedule of fewer than five daily treatments per week
Internal mammary lymph nodes lying just under the front end of the ribs adjacent to the breast bone
Iridium wire implant radioactive wire which can be inserted into tissue for a short time to give a boost dose locally eg to the tumour bed
Isodose plan a computer generated plan which shows the distribution of dose within the treated volume
Linear accelerator modern megavoltage radiotherapy machine
Local recurrence tumour recurrence within the irradiated volume
Lymphoedema swelling, usually of the arm
Medical oncologist a non-surgical cancer specialist with a main interest in cancer chemotherapy
Megavoltage machine high voltage radiotherapy machine with a deeply penetrating beam
Metastases distant spread of tumour
Morbidity unwanted side effects of treatment
Mortality rate expected rate of survival in a group of patients
Multi-centre studies research carried out by several co-operating cancer centres
Necrosis tissue death
Nerve block injection into a nerve to control pain
Nerve roots the part of the nerve as it arises from the spinal cord
Normal tissue tolerance normal tissues differ in their ability to tolerate high doses of radiotherapy. Clinical oncologists aim not to exceed the tolerance dose
Opiates strong pain drugs of the morphine family
Palliation to relieve distress and improve the quality of life, rather than length of life or cure
Paraesthesiae pins and needles or abnormal sensations
Prone  lying face downwards

Quality assurance  the essential measures taken to ensure the safe delivery of radiotherapy

Radiation pneumonitis  a pneumonia like syndrome caused by radiotherapy which usually responds to corticosteroid therapy

Radiographer  a member of the team responsible for the safe delivery of radiotherapy who runs the radiotherapy machines

Scapula  the shoulder blade

Semi-supine  lying on the back slightly rolled over to one side

Simulation  planning of radiotherapy with the patient in the treatment position

Sternum  the breast bone

Subcutaneous tissue  tissue just beneath the skin

Supine  lying on the back

Tail of the breast  the part of the breast that lies just below the axilla

Tangential fields  glancing fields of radiation across the chest wall or breast

Telangiectasia  skin changes due to radiotherapy which are like tiny red blood vessels, similar to those seen after a burn

TENS machine  for the treatment of pain

Thoracic  relating to the chest

Ultra-sound  diagnostic pictures produced with the use of sound waves

We are grateful for the assistance received from: Mrs Jan Millington and the RAGE Committee, who obtained the consents of those of their members who were included in this review; Dr P Anand (Royal London Hospital), who examined 6 of the patients; Professor Walter Holland (St Thomas’s Hospital) for advice on statistics; Dr Jane Maher (Mount Vernon Hospital), chairman of the multidisciplinary committee on the management of adverse effects following breast radiotherapy, whose report is complementary to this report; and Mr Christopher Squire, the College’s Audit Adviser, for administrative support during the review and his help in preparing this report for publication.

We are extremely grateful for the generous help we received from the staff of the 15 cancer centres we visited and appreciate that this entailed extra work for very busy people. Every cancer centre went to a great deal of trouble to make sure the information we required was available on the days of our visits.

This review has been supported by a grant from the Clinical Audit Unit of the Executive of the NHS for England.


Hoang P, Ford DJ, and Burke FD. Post mastectomy pain after brachial plexus palsy; metastases or radiation neuritis?. Journal of Hand Surgery 1986;11B: 441-3.


Øvergaard M, Bentzen SM, Christensen JJ and Madsen EH. The value of the NSD formula in equation of acute and late radiation complications in normal tissues following 2 and 5 fractions per week in breast cancer patients treated with post-mastectomy radiation. Radiotherapy & Oncology 1987;9:1-12.


## Appendix A: Patient data form

**BRACHIAL PLEXUS NEUROPATHY CLINICAL REVIEW. PATIENT ASSESSMENT.**

**CENTRE VISITED**

**PATIENT**

<table>
<thead>
<tr>
<th>Code</th>
<th>DoB</th>
<th>Age</th>
<th>Menopausal status</th>
<th>Relevent history</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>☐ Premen ☐ Perimen ☐ Postmen ☐ not stated</td>
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</tbody>
</table>

**BREAST CANCER**

<table>
<thead>
<tr>
<th>Site</th>
<th>Stage</th>
<th>Surgical Pathology</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
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</tbody>
</table>

**SURGERY**

<table>
<thead>
<tr>
<th>Surgeon</th>
<th>Date of surgery</th>
<th>Physiotherapy policy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Surgical complications ☐ none ☐ haematoma ☐ fluid ☐ delayed healing

**RADIOThERAPY**

<table>
<thead>
<tr>
<th>Centre</th>
<th>Clinical Oncologist</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Method of immobilisation

Patient moved between fields ☐ Yes ☐ No

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Technique</th>
<th>Gap policy</th>
<th>Dose measured during RT?</th>
<th>Treatment frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Yes ☐ No</td>
<td>☐ Yes ☐ No</td>
<td>☐ 0 ☐ Defined</td>
<td>☐ Yes ☐ No</td>
<td>☐ Daily ☐ Alternate days, M W F ☐ Alternate days, M W F T Th ☐ other...</td>
</tr>
</tbody>
</table>

CA CHAIN RT ☐ Yes ☐ No

<table>
<thead>
<tr>
<th>Start date</th>
<th>Machine</th>
<th>Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All fields treated each session ☐ Yes ☐ No

<table>
<thead>
<tr>
<th>Dose to reference point</th>
<th>Max. tissue dose</th>
<th>No. fractions</th>
<th>Fraction size</th>
<th>Total time in days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

---

*Brachial Plexus Neuropathy following Radiotherapy*
## CHEST WALL / BREAST RT

<table>
<thead>
<tr>
<th>Field Size</th>
<th>Separation</th>
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</thead>
<tbody>
<tr>
<td>All fields treated each session</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dose to reference point</th>
<th>cGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. tissue dose</td>
<td>cGy</td>
</tr>
<tr>
<td>No. fractions</td>
<td></td>
</tr>
<tr>
<td>Fraction size</td>
<td>cGy</td>
</tr>
<tr>
<td>Total time in days</td>
<td></td>
</tr>
</tbody>
</table>

**Start date** _________________________________ **Machine** _________________________________

**Technique** _________________________________ **Field size** _________________________________

## BOOST RT

<table>
<thead>
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<th>Dose to reference point</th>
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<td>Max. tissue dose</td>
<td>cGy</td>
</tr>
<tr>
<td>No. fractions</td>
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</tr>
<tr>
<td>Fraction size</td>
<td>cGy</td>
</tr>
<tr>
<td>Total time in days</td>
<td></td>
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</tbody>
</table>

**Start date** _________________________________ **Machine** _________________________________

## IMPLANT

<table>
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<tr>
<th>Dose</th>
<th>_________________________________</th>
</tr>
</thead>
</table>

**Start date** _________________________________ **Technique** _________________________________

## CONCURRENT FACTORS

Concurrent factors

## ADJUVANT CYTOTOXIC CHEMOTHERAPY

<table>
<thead>
<tr>
<th>Adjuvant chemotherapy</th>
<th>No</th>
</tr>
</thead>
</table>

**Type** □ Neoadjuvant □ concurrent □ post RT

<table>
<thead>
<tr>
<th>Starting date</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of courses</td>
<td>Relevant complications</td>
</tr>
</tbody>
</table>
### ADJUVANT HORMONE THERAPY

Adjuvant hormone therapy  □ Yes □ No  
Type □ Neoadjuvant □ concurrent □ post RT  
Starting date  
Schedule □ Tamoxifen □ Oophorectomy □ RT menopause □ Other…

### LOCAL RECURRENCE

Local recurrence  □ Yes □ No  
Site of recurrence  
Extent  
Date recognised  
Management  

### METASTASES (Outside Treated Volume)

Metastases  □ Yes □ No  
Sites of recurrence  
Extent  
Date first diagnosis  
Management  

### ACUTE RT SIDE EFFECTS

Symptoms  □ Yes □ No  
Skin reaction  □ Yes □ No  
Comments  

---

Appendix A: Patient data form (continued)
### LATE RT SIDE EFFECTS (from the records)

<table>
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<th>Effect</th>
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<th>No</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Skin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcutaneous fibrosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone necrosis &amp; fracture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary fibrosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphoedema of arm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stiff shoulder</td>
<td></td>
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</tbody>
</table>

### POSSIBLE BRACHIAL PLEXUS NEUROPATHY

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<thead>
<tr>
<th>Time course</th>
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</table>

<table>
<thead>
<tr>
<th>Symptoms</th>
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</table>

<table>
<thead>
<tr>
<th>Neurologist opinion</th>
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<table>
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<th>Further action</th>
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</table>

<table>
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<tr>
<th>Impression</th>
<th></th>
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</table>
Appendix B: Cancer centre data form

BRACHIAL PLEXUS NEUROPATHY CLINICAL REVIEW – CANCER CENTRE REVIEW

Cancer Centre visited
Code
Population served
New cancer patients p.a.
Breast cancer patients p.a.

Management structure

Staffing levels

Machines then

Machines now

Combined clinics □ Yes □ No
Specialist consultants □ Yes □ No
Specialist breast nurses □ Yes □ No
Breast counselling □ Yes □ No
Breast literature □ Yes □ No
Lymphoedema clinic □ Yes □ No
Pain relief clinic □ Yes □ No
Hospice and Home care □ Yes □ No

Written protocols then

Written protocols now
### Appendix B: Cancer centre data form (continued)

<table>
<thead>
<tr>
<th>Category</th>
<th>Then</th>
<th>Now</th>
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</thead>
<tbody>
<tr>
<td>Simulation</td>
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<tr>
<td>Lung volume measurements</td>
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<td>Immobilisation</td>
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<tr>
<td>Axilla irradiated</td>
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<td>Gap policy</td>
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<td>All fields treated each session</td>
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<td>QA programme</td>
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<td>Medical audit</td>
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<td>Postgraduate training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breast cancer publications</td>
<td></td>
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</tr>
</tbody>
</table>
Appendix C: Consequences and symptoms of radiation as documented by RAGE

Amputation of arm at elbow or shoulder.
Spontaneous fractures of bone which heal slowly or not at all. Bones affected are ribs, arm, collar bone and shoulder blade. Vertebrae and sternum “crumbling”.


Severe unreliable pain in all or any affected area. Strong opiates prescribed in many cases. Various pain regimes, e.g. nerve blocks, tens machine, acupuncture, cordotomy, steroid injection, various drug regimes not effective.

Lymphoedema. Swelling of the arm on affected side often accompanied by intense pain and restricted movement. Can lead to infection and cellulitis.

Respiratory problems caused by lung damage. Condition often referred to as “pneumonitis”. Breathlessness and much distress. Some cases treated for life by steroids, nebulisers. Similar damage to trachea and bronchi and chest wall. Death has occurred of this complication.

Skin conditions which are difficult to treat and can become chronic. Burns, sores, severe rashes akin to shingles. Plastic surgery needed in some cases, or mastectomy (following lumpectomy). Inflammation and intense sensitivity. Bad scarring, scleroderma.


A miscellany of less common problems, e.g. underfunctioning thyroid, general arthritic conditions.

Appendix D: RAGE’s analysis of replies to their questionnaire

RAGE sent out 640 questionnaires and had 180 replies (28%); this is an analysis of the replies.

1. Has it been admitted that your symptoms are caused by radiotherapy?
   60% have been diagnosed as having radiotherapy damage, 40% have not.

2. Are you on medication for pain relief? If so, what medication are you using? Is it effective?
   70% are on some form of medication, 30% do not take medication. Medication range from opiates, anti-depressants and steroids to aspirin and paracetamol. Of those taking medication, 50% get no relief at all, 10% sometimes get some relief, 40% found their medication effective (these tended to be the women on opiates).

3. Have you had surgery to relieve symptoms?
   Only 10% have had any form of surgery (mostly BP decompression).

4. Have you attended a pain clinic? Was it helpful?
   25% have attended a pain clinic; 90% found it helpful.

5. Have you received physiotherapy? Was it on the NHS? Was it effective?
   60% have received physiotherapy; 90% were treated on the NHS; only 20% found it effective.

6. Have you received acupuncture? Was it on the NHS? Was it effective?
   25% have received acupuncture; approximately half received it on the NHS; only 10% found it effective.

9. Have you received any other therapy?
   The most popular alternative therapies were reflexology and massage.

10. Have you received any psychological support?
    Only 5% had received psychological support: of these 78% said it was helpful.

11. Do you use any aids?
    50% use some form of aid.

12. Overall, how do you consider you have been treated?
    50% feel they have been treated indifferently, 25% badly and 25% well.

13. What would you welcome now in the way of treatment?
    Ranking of answers:
    Expert diagnosis with honest prognosis 1st
    Effective pain control 2nd
    Alternative therapies 3rd
    Psychological counselling 4th
    Surgery 5th
Appendix E: Patient position during radiotherapy: 13 different policies

We identified these 13 different treatment policies in use (over the 14 years covered by the study) in the 15 cancer centres we visited:

**Policy 1**
Chest wall treated with the patient semi-supine, hand on forehead and head turned to the other side.

Nodes treated with the patient supine, arm at right angles or on hip.

Now treated supine with minimal movement of arm. No breast board or arm pole used.

**Policy 2**
Chest wall only treated, with patient supine lying on simple wedged pillows so that the sternum is horizontal, and the arm raised.

**Policy 3**
Chest wall and nodes treated with the patient static using an arm pole and pillows. Now treated on a sophisticated breast board and with a sophisticated arm pole.

**Policy 4**
Chest wall and nodes treated with the patient static using an arm pole and pillows.

Now treated on four sizes of wedged foam pillows and using a sophisticated arm pole.

**Policy 5**
Chest wall treated with the patient semi-supine with the hand on the top of the head and the elbow forward.

Nodes treated with the patient flat and the hand on the hip.

Now treated in a static supine position with the arm at right angles using an arm pole.

**Policy 6**
Chest wall treated with the patient semi-supine with the arm up.

Nodes treated with the patient supine and the arm down.

Now treated with the patient static, lying flat on a breast board with the arm at right angles with an arm pole.

**Policy 7**
Chest wall treated with the patient semi-supine with the arm up.

Nodes treated with the patient supine.

Now, since 1984, patient treated supine, with wedged pillows and the sternum horizontal, with both arms up on a double arm pole.

**Policy 8**
Patient always treated in a static position, supine with wedged pillows, and the arm up using a sophisticated arm pole.

**Policy 9**
Chest wall treated with the patient semi-supine and the hand on the forehead.

Nodes treated with the patient supine and the arm down with the hand on the hip.

Now treated in a static position, supine with a sophisticated double arm pole.

**Policy 10**
Chest wall treated with the patient supine with the sternum horizontal, the arm up and the hand behind the head.

Nodes treated in the same position with minimal movement of the patient, or floor rotation, for the best match of fields.

Now treated in the same way but with the patient lying on a breast board and polythene wedged with a pillow under the knees.

**Policy 11**
Patient treated in a static supine position with the sternum horizontal using polythene wedges, and the arm up with an arm pole, and the head turned to the other side.

**Policy 12**
Chest wall treated with the patient in a semi-supine or supine position with the arm up.

Nodes treated supine with the arm moved down a little.

Now treated with the patient static, supine with the sternum horizontal using wedged pillows, the arm at right angles with an arm pole and the head straight.

**Policy 13**
Patient treated in a static supine position with the sternum horizontal with wedged pillows, arm at right angles with an arm pole and the head straight.
Appendix F: Example of a cancer centre’s radiotherapy protocol and work instructions

13 of the 15 centres we visited have formal written protocols and work instructions to meet the varied requirements of patients with operable breast cancer; the remainder have protocols in preparation. Most but not all centres have agreed protocols but others have several variations for different consultants. This centre’s protocol and work instructions are included here as examples of modern practice and to show the level of detail required.

Radiotherapy Protocol for Carcinoma of the Breast

This protocol applies to the irradiation used for the conservative treatment of early breast cancer and those patients requiring post-mastectomy radiotherapy for breast cancer. Whilst there will be minor adjustments necessary due to the variation in surgical practice prior to referral for radiotherapy, this protocol covers the basic principles of technique and policy used at this centre. Radiation for locally advanced breast cancer is individually planned, but these guidelines should form a basis for the technique.

Indications for Post-Mastectomy Radiotherapy (Any major or both minor):

Major Criteria
- deep margin involvement
- skin involvement
- size > 4 cm. (smaller in small breast)
- ≥4 nodes positive

Minor Criteria
- node positive
- histological grade III tumour

Patients with T1G1N0X carcinomas

There is uncertainty about the role of radiotherapy in these patients after wide local excision. If lymph node status is unknown and negative then these patients should be considered for entry into the BASO II trial. If lymph node status is unknown then these patients should be considered for entry into the CRC trial examining the role of local prophylactic radiotherapy.

1. Tangential Irradiation of the Intact Breast/Chest Wall.

1.1 Set-up position.

The patient lies on a wedge chosen so that the sternum is horizontal to the couch top. The arm is abducted with the humerus at 90° from the trunk and horizontal if possible. A suitable height for the hand rest is chosen to enable the patient to maintain this position comfortably. The patient lies with their head turned to the contralateral side.

1.2 Field margins.

a. Medial border: 1 to 2 cm. to the ipsilateral side of midline to cover palpable breast tissue with a margin of 1 cm. For tumours of the medial quadrants the midline may be used.

b. Superior border: this is positioned where the lateral tangential field can be brought in without the arm being within the field. It should not be above the suprasternal notch.

c. Inferior border: should be 1 cm. below the infra-mammary fold routinely but may need to be below this in larger breasts to ensure the whole breast is within the treatment field as seen on simulation.

b. Lateral border: 1 cm. outside the lateral palpable border of breast tissue.

1.3 Outlining and Simulation

A single central outline is produced using the Proforma device. This is undertaken on the simulator after the clinical borders above have been defined. The tangential fields are simulated. This process should ensure that a maximum 2.5 cm. of lung is included (ideally less than 2 cm.) as measured in the central axis. A vidi-print will be taken of the tangential lung volume and will be stored in the patients notes. In addition, orthogonal vidi-prints taken at 0° and 90° through the isocentre with a reference field size enable the lung volume in the central outline to be put on to the central outline.

1.4 Planning

A computer generated plan will be produced with homogeneity through the treatment volume of ± 5% in a midplane outline. Lung correction will be applied using a density correction of 0.25. Where possible, wedges on the median tangential field should be avoided and opposed fields used.

1.5 Machine Energy

For intact breasts a 6 MeV linear accelerator should be used. No bolus should be used. For chest wall irradiation (post mastectomy) a 6 MeV linear accelerator with no bolus should be used if the supraclavicular fossa (SCF) is also to be irradiated. If the SCF is not to be irradiated then an 8 MeV linear accelerator is acceptable with 1 cm. of bolus over the chest wall.

1.6 Dose Prescription

For invasive carcinoma 40 Gy in 15 fraction in 21 days with daily fractionation of both fields prescribed to the intersection point.

Ductal carcinoma in situ (DCIS) will also receive 40 Gy in 15 fractions.
1. **Boost**

A boost may not be required in the following circumstances:

1. There are good resection margins (at least 1 cm.)
2. The lesion is < 2 cm.
3. The lesion is of histological grade I or II.
4. The absence of extensive intraductal carcinoma.

Consider a boost in the following circumstances:

1. It is not certain that clear margins have been obtained.
2. There is extensive intraductal carcinoma.
3. There is vessel invasion.
4. The lesion is of histological grade III.

**Electron therapy:** Previously following a standard breast treatment of 40 Gy in 15 fractions an electron boost of 15 Gy in 5 fractions was used. Using electron therapy these patients have a 50% incidence of moderate/severe telangiectasia at 2 years. Therefore we recommend a standard dose of 10 Gy in 5 fractions in 7 days is prescribed at 100%. The 90% depth should be recorded.

If there is uncertainty about margin involvement consider an interstitial implant or a dose of 15 Gy in 7 fractions. No bolus should be used. The electron energy should be prescribed following a clinical assessment of the depth of the tumour bed. The size should encompass the scar plus 1 cm. margins either end with an appropriate field width, which should not be less than 4 cm. Care should be taken to try and avoid the nipple within the field.

The need for a boost should be clearly identified on the tangential field treatment card. The boost will be marked on to the patient skin during the last week of tangential irradiation so that the boost therapy may commence with no delay.

2. **Nodal Irradiation**

2.1 **Ancillary Radiotherapy**

When a full level 2 or 3 axillary dissection has been performed no radiotherapy should be routinely given to the axilla. In the occasional circumstance where it is considered important to do so, the posterior axillary field should be given with daily fractionation. Where axillary radiation is to be given following axillary sampling or a surgically untouched axilla the supra clavicular fossa (SCF) is routinely irradiated.

2.2 **Technique for Matching Fields**

A floor rotation technique will be used to allow a match to the superior border of the tangential fields.

2.3 **SCF Irradiation Alone**

The SCF may be electively irradiated in those patients who have undergone an axillary clearance where there are 4 or more positive nodes, or in patients who are node positive with high grade tumour. Where this is undertaken the medial border is 1 cm. to the ipsilateral side of midline. The lateral border is at the medial edge of the humeral head. Laryngeal shielding is not used routinely. Leading may be applied to the apex of the lung along the inferior margin of the clavicle. A vidi-print will be taken to record this field.

2.4 **Axilla and SCF**

The medial margin of the SCF is as described above. A posterior axillary field (standard size 8 x 6 cm. or 7 x 5 cm. is applied. This may overlap with the tangential fields. Humeral head shielding on the anterior SCF field is routinely applied and should lie along the axis of the humeral shaft, shielding the head of humerus completely. The lateral border of the anterior field should not extend lateral to the posterior axillary field. Vidi-prints are taken for verification.

2.5 **Dose Prescription**

a. **SCF:** 40 Gy in 15 fractions over 21 days applied dose using 6 MeV photons. No bolus is used.

b. **Axilla and SCF:** 40 Gy in 15 fractions over 21 days (5 fractions per week) prescribed to the anterior field, 9 fractions are prescribed to the posterior axillary field over 21 days (3 fractions per week) to bring the midline axillary dose to a total of 40 Gy (a separation at the mid point of the posterior axillary field is taken routinely).

3. **Relationship to Adjuvant Chemotherapy Treatment**

3.1 **Intensive Anthracycline Containing Regimes.**

Where regimes such as FEC are to be used all chemotherapy will be given prior to radiotherapy.

3.2 **CMF (Bonnadonna) Chemotherapy.**

All 6 courses of CMF may be given prior to radiotherapy or alternatively a sandwich technique of chemotherapy-radiotherapy-completion of chemotherapy may be used. Chemotherapy may start soon after the surgery. Radiotherapy will take place between the 2nd and 3rd courses of chemotherapy or between the 3rd and 4th as arm movement and wound healing allow. Radiotherapy and chemotherapy should not be given concurrently. Following completion of the radiotherapy, chemotherapy may then be re-started.

4. **Care During Radiotherapy**

4.1 **Full Blood Count**

Where a patient has had prior chemotherapy a full blood count should be undertaken prior to commencement of radiation treatment.

4.2 **Review Clinic**

Patients will be reviewed once per week during their radiation courses.
4.3 Skin Care Information
Skin care information will be provided as per skin care information leaflet. The nursing staff in review clinic will give advice and appropriate support as necessary. Information on skin care after their radiotherapy be will provided.

4.4 Access To Support Services
Referral to support personnel should be considered: e.g. Breast Care Nurse & Physiotherapy for arm mobilisation.

5. Follow Up Arrangements
A follow up appointment in the peripheral clinic will be given. A letter detailing the treatment, aftercare instructions and any other important information forwarded to the General Practitioner.

Work Instructions for Breast Treatment.

A Treatment Card Calculation and Preparation
This must be carried out by one radiographer and checked independently by another, one of whom must be of a senior grade:

B The Tangential Breast Assessment Card.
1. Ensure that the treatment card has an accompanying simulation sheet and treatment plan.
2. Ensure that the treatment card and plan have the same patient name and unit no.
3. Check that the setting up instructions on the card are identical with the simulator sheet, including polywedge angle, armpole notch and head support. Transfer the junction alignment instruction to the front of the card, i.e. straight or rotate couch.
4. Verify the scale of the plan by measuring one parameter and checking this against the dimension given on the plan. Check the set-up parameters on the plan against the front of the card. Transfer details of the f.s.d., gantry angles, t.s.d.s to the front of the card.
5. Check the dose calculation, calculate the daily field given doses, monitor units (and wedged monitor units where appropriate) and transcribe the information to the appropriate area inside the card.
6. Ensure that the fractionation is clearly indicated on the dose columns inside the card.
7. Ensure the setting up data is complete, unambiguous and clearly documented on front of the card.

C The Supra Clavicular Fossa and Axilla Card.
1. Check the data on the front of the treatment card against the simulator sheet, including field sizes, shape and position of shielding and the A/P axillary separation.
2. Check the dose calculation with the appropriate table in the treatment data book.
3. Transfer data to the inside of the card, calculate the monitor units and clearly indicate the fractionation.

Any omissions or discrepancies discovered by the second radiographer must be drawn to the attention of the first and corrected before the first treatment. A third radiographer must check the treatment card within the first 4 treatments.

D Preparation of the Verification Card
The data must be entered by one radiographer and checked by another, one of whom must be of a senior grade.

1. Information for the verification system must be taken from the plan and the treatment card. Cross-checking should be carried out to ensure at information from these sources is identical.
2. The verification tolerance used should ensure that the set-up is checked with maximum accuracy for all parameters for each field.

E Set Up Procedure.
Two radiographers must be present to treat all the fields of each fraction. The simulator sheet should be referred to during the set-up process for all of the treatments.

1. Position the patient on the specified polywedge with their shoulders level with the top of the wedge.
2. Ensure the correct notch is set on the armpole. The patient’s hand should grip the handle loosely with thumb around the same side of the handle as the fingers.
3. Ensure that the patient is straight and correct any rotation using the lasers.
4. Position the arm at right angles to the body using the lateral laser. Ensure that the junction line is drawn on the patient right into the axilla so at the SCF field can be accurately aligned with the tangentials.

The lateral field should always be treated first as variations in patient position are more often demonstrated on this field. After the lateral field has been treated the position of the patient’s arm must not be altered.

5. Set the f.s.d. to the point of the arrow on the medial volume line.
6. Measure the position from the arrow to the isocentre with the ruler horizontal using the sagittal laser or the machine cross (when the gantry is at 0°) to do so. Measure this distance infra mammary if it is impossible to hold the ruler horizontally at the level of the arrow. In this case, the original volume line must be accurately kept.
7. Lateral tangential field: For the angled couch technique, set the gantry to a lateral position and angle the couch so that the superior field edge runs along the junction line.
with the SCF field. Then set the prescribed gantry angle, rotating the couch so that the superior edge of the light field matches the line drawn into the axilla. This is essential in order to match the field edges of the lateral tangential field and the SCF field.

The field light should fit the simulated field marks to within 0.5 cm.

8. **Medial tangential field**: Set the medial gantry angle and check the horizontal measurement. If the field falls short of the simulator field marks check the f.s.d as the patients often relax between fields. Angle the couch as above as necessary. For setups with a straight couch the field light should cross the junction line at the point where the sagittal laser crosses the junction line.

9. **Supraclavicular fossa field**: The SCF field should be set with its inferior border matched to the junction line, paying particular attention to the axilla. If the SCF field does not splash into the axilla and matching is difficult move the bed laterally so that the light beam can be seen in the axilla. Move the couch to fit the light field to the marked medial and lateral field borders after the diaphragm angle is set.

10. **Posterior axillary boost field**: Ensure that the post axilla field is completely over the polywedge. Set the field to the treatment marks then rotate gantry to 180° and set the diaphragm rotation.

11. Set the lateral laser so that it skims the wedge top at the centre of the field. This ensures that the post axilla is set at 100 cm. f.s.d.

F Additional first treatment checks

Ideally the senior in in charge of the unit should see all first set-ups, especially those of a complex nature, as she/he holds the responsibility for all radiotherapy procedures carried out on the unit.

Prior to the treatment of either tangential breast field the following checks must be carried out with the patient in the correct treatment position:

1. The field light for the medial and lateral field fit the simulated field marks to within 0.5 cm.
2. The t.s.d. measurements are within 2 cm.
3. Check all the treatment parameters against the plan before treating the first field.

Prior to treatment of the post axilla check that the separation of the SCF field and the post axilla is within 0.5 cm of the prescribed value. If it is not, the % depth doses must be recalculated.

G Possible Problems and Solutions

With any apparently poor match of the light field to skin marks, check that the set-up parameters are correct before adjusting the patients position.

1. If the field light is inside the lateral field marks, lift the patient’s thorax off the wedge and rotate them away from the machine head to move the field marks up. Reset the side crosses and set the field up again.
2. If the above does not work sit the patient up and ask them to lie down looking away from the treated side.
3. If the field light is splashing outside the light field marks, lift the patient’s thorax off the wedge and rotate them towards the machine head to move the treatment marks downwards then reset the side crosses.
4. If the above does not work sit the patient up and ask them to lie down looking towards the treated side.

If the above do not work, or there are other problems, call a superintendent to see the set up. It may be necessary to get a clinician to see the patient on set to decide if the set up is acceptable. If it is not, the patient will have to be re-simulated. Simulator attendance should be arranged for a time when the relevant clinician can be present at the re-screening.

If the patient has lost their skin marks and reconstruction on the machine proves to be impossible, the patient must be re-simulated.
Appendix G: Example of an isodose plan for tangential fields across the breast

LEFT BREAST

M590\(^{60}\)Co 90 cm. SSD to breast bridge

NO WAX, NO BOLUS

LAT
14 W x 18
Wt. = 0.78
(WEDGE 3)

MED.
14W x 18
Wt. = 1
(WEDGE 3)

No normal

90 cm. SSD to breast bridge

90 cm. SSD to breast bridge
Appendix H: Example of the double arm pole in use for a four field technique

1 Posterior axilla field
2 Supraclavicular field
Pb Lead shield over head of humerus and apex of lung
Anatomy of the shoulder, showing the brachial plexus in yellow
BPN status and cause by year of treatment (see also Table 1)