ERGONOMIC ASSESSMENT OF MAMMOGRAPHY UNITS

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AG Gale, N Hunter, C Lawton and K Purdy
Applied Vision Research Centre, Loughborough University

Enquiries
Enquiries about this report should be addressed to:
Professor Alastair Gale
Applied Vision Research Centre
Loughborough University
Loughborough
Leicestershire
LE11 3UZ

Tel: 01509 63 5703
Fax: 01509 63 5709
Email: a.g.gale@lboro.ac.uk

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Fulwood House
Old Fulwood Road
Sheffield
S10 3TH

Tel:0114 271 1060
Fax: 0114 271 1089
Email: info@cancerscreening.nhs.uk
Website: www.cancerscreening.nhs.uk

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EXECUTIVE SUMMARY

An ergonomic assessment of mammography machines was previously carried out for the NHS Breast Screening Programme in 1997.* Since 1997, some basic changes have occurred to many mammography machines and their associated hardware (referred to in this report as 'units') that have reduced the frequency with which harmful tasks are carried out. These include developments such as the introduction of motorised units, lightweight units with isocentric rotation and the provision of more accessible controls. When implemented properly, all of these developments can serve to make the mammography task less physically demanding for the mammography practitioner.

Some recommendations in the 1997 report have not been taken up by manufacturers, eg non-reflective glare on compression paddles or motorised tube heads. It is likely that a number of factors have contributed to this, such as cost, feasibility and development time. Overall, mammography units are more ergonomic, but there are variations in design between different manufacturers and some issues still need to be addressed. Consultation with the NHS Breast Screening Programme (NHSBSP) and discussion with both individual mammography practitioners and regional training centres revealed that many mammography practitioners still experience musculoskeletal problems. Wrist, thumb and finger problems emerged as being most troublesome in the groups studied. However, although such wrist/thumb problems were noted in 1997, they were not at that time considered to be as extensive as issues such as back problems. In combining injury reports with those received by the NHSBSP, it would appear that back, shoulder, elbow and knee problems are now less prevalent than wrist/thumb problems.

The remit of the current ergonomic assessment was to establish the present situation, identifying areas where improvement is needed and making recommendations for alteration to the 1997 report in order to achieve improvement. Consequently, this work concentrates more on current and future aspects than on specifying the exact degree or cause of improvement over past years. The 1997 set of recommendations was made to address the ergonomic challenges in a number of different ways, and so it is likely that a number of factors are responsible for the improvements seen since then.

As problems with areas of the lower limbs remain prevalent, and as some recommendations from the 1997 report have not been implemented, further measures may be required. In addition, although the levels of back and shoulder pain have reduced, it is still necessary to prevent a return to the previous situation and, ideally, to reduce levels further. Other factors such as the change in the mean age of the radiographer population and different work patterns may well be relevant too, and changes in the immediate future, such as the move towards digital capture, should be anticipated as far as is reasonably feasible.

The factors identified as causing wrist and hand pain are inserting and ejecting films from the bucky, control locations on handles, mounting film onto the viewer and changing the exposure chamber settings. Currently, digital technology is mostly used for symptomatic work, but it is expected to become widespread in the screening programme. Digital mammography units reduce many of the factors thought to be causing wrist and hand pain, and so will in theory be beneficial in reducing this in the long term. However, some problematic aspects are being carried over from analogue to digital capture designs without notable improvement. The task of positioning the breast on the breast support table and exposing it still remains. It is these tasks which result in the most extreme and awkward postures and therefore where the highest risk of injury may occur.

* Gale AG, May J. *An Evaluation of Musculoskeletal Discomfort Experienced by Radiographers Performing Mammography.* NHS Breast Screening Programme 1997 (NHSBSP Publication No 36).

There are also some new ergonomic issues related to digital technology that are potentially of concern. A small number of mammography practitioners have observed that when conducting the mediolateral view there may well be more excessive reaching and twisting with a digital unit than with an analogue unit; however, this has not been quantified. It has been suggested that this is due to the lower height and larger size of the head of the unit arm, which acts as a larger obstacle to mammography practitioners than the head of the analogue unit when viewing the breast.

There is a risk that the removal of some tasks will result in more frequent repetition of the remaining higher risk task elements. The removal of certain tasks will mean that the body is given fewer and/or shorter rest breaks from adopting awkward postures and between repeating the same actions. Currently, the task element of processing x-ray films provides a built in break, during which awkward postures are not adopted. With the removal of these physically less demanding tasks which encourage neutral postures, consideration needs to be given to how naturally occurring micro-pauses can be built into, and become part of, the digital task.

1. INTRODUCTION

1.1 Background

In 1997, the Applied Vision Research Institute, University of Derby (now the Applied Vision Research Centre, Loughborough University)* examined whether radiographers performing mammography were experiencing musculoskeletal discomfort or injury and to what extent the design or layout of the equipment were potentially contributing factors.

The work involved a national questionnaire survey of radiographers to determine the extent of self-perceived musculoskeletal injury, a body map discomfort survey to examine the local areas of pain experienced by radiographers, taking physical measurements of mammography units and comparing these with the anthropometric measurements of radiographers, and finally conducting a task analysis of the mammography screening process to understand how the equipment was operated and to observe exactly where in the sequence of operation problems were occurring.

These approaches enabled researchers to understand the extent of musculoskeletal injury and to determine whether any association existed between the injuries and any areas of the equipment design or features of the task of performing mammography. In particular, these approaches allowed researchers to investigate the precise aspects of mammography that were subjecting radiographers to the four basic factors that harm the musculoskeletal system, ie excessive bending and twisting, static working postures, forceful movements and repetitive work.

As a result of these observations, a series of recommendations was proposed to improve the design of the mammography units. These recommendations aimed to reduce the frequency with which radiographers needed to adopt harmful postures. Additionally, a video tape was made to encourage radiographers to be aware of the potential for injury and to adopt appropriate postures.

Since then, there have been changes to many aspects of mammography and breast screening. Manufacturers now stress what they consider to be the ergonomic features of their systems. As systems have become more ergonomic and less tiring to use, the situation as addressed by the 1997 report has changed. Although most of these changes are expected to be beneficial to both users and productivity levels, it should be recognised that such advantages may also introduce new issues to address, such as the need to account for the latest hardware configurations and the changing demands on users that could be associated with the increased speed and repetition that physical improvements may allow.

Additionally, several innovations have taken place, such as the introduction of digital acquisition technology, breast biopsy facilities and manufacturers' bespoke systems that enable imaging of more breast tissue. Consequently, it has been suggested that it may be time to update the previous work, as these mammography imaging units have changed and may require somewhat different operating postures and related tasks.

This report details work that has been carried out since 1997 in order to address the new situation. For consistency and brevity, this report refers to mammography machines and any tools or hardware integral to them as 'mammography units'.

* Gale AG, May J. *An Evaluation of Musculoskeletal Discomfort Experienced by Radiographers Performing Mammography.* NHS Breast Screening Programme 1997 (NHSBSP Publication No 36).

1.2 Scope

As it is some time since the 1997 report was published, an updated version is required; however, only a certain degree of change was anticipated and hence this work essentially comprises an update and modernisation of the previous work rather than a full repeat of it. In particular, it was not thought necessary to carry out another national survey of mammography practitioners with regard to potential musculoskeletal injuries because the practitioners' working situations have remained similar. Any amendments by manufacturers since the first survey should have been to improve the ergonomics of the equipment following the previous recommendations. Therefore, smaller scale investigation, consultation and information from the NHSBSP have been used to direct attention to specific areas of concern. As a result, the current work comprised the following:

- the previously published report was reviewed in light of developments in mammographic technology
- the mammography units that are currently in use were identified along with which breast screening services are using them
- these mammography units were compared with both the advice in the previously published report and the manufacturers' ergonomic claims in their literature; this would quantify how well the unit meets the advice and how well the manufacturers comply with it
- task analyses were carried out for a sample of mammography practitioners, representing upper and lower anthropometric percentiles, operating these mammography units; this identified any possible changes in the overall task since the previous report and also allowed evaluation of the current potential for musculoskeletal harm (eg repetitive strain injury (RSI) or work related upper limb disorder (WRULD)). The types of postures involved and the frequency of adopting such postures were determined.

1.3 Changes since the previous report

1.3.1 Musculoskeletal problems

The 1997 report highlighted that musculoskeletal injuries were particularly affecting body areas such as the shoulders, back, elbows and knees. A series of recommendations were proposed regarding the technique that mammography practitioners should adopt when using the equipment. This may have contributed to the reduction in reports of this type of musculoskeletal complaint by making mammography practitioners more aware of the risks posed by mammography and how best to ameliorate them.

However, correspondence with the NHSBSP and individual breast screening units has revealed that musculoskeletal injury and, in particular, RSI affecting the thumbs and wrists remains a particular problem for mammography practitioners. The fact that musculoskeletal pain (particularly in the thumbs and wrists) remains a problem rightly concerns the NHSBSP and, consequently, this report examines those mammography machines currently in use.

1.3.2 Past and current mammography units

The mammography units examined by the 1997 report are listed below:

GE Senographe 600T
Lorad Mark III
GE Senographe DMR
Siemens Mammomat 2
Mamex DCS
Picker Sureview
Philips MammoDiagnost UC
Philips MammoDiagnost UM

As can be seen from the following list, very few of the mammography units in use in 1997 are still currently used in the NHSBSP:

	Number of units in use
Siemens Mammomat 3000	211
Lorad Mark IV	81
GE 800T	66
GE DMR+	65
Instrumentarium Alpha RT	17
Siemens Mammomat 300	8
Instrumentarium Diamond	6
Siemens Mammomat 1000	5
Instrumentarium Performa	4
Siemens Mammomat 2/2S	4
Planmed Sophie	4
Philips MammoDiagnost S	1
Siemens Mammomat 3	1

This information was compiled in July 2004 (source: NHSBSP *Equipment Fault Report: December 2003 to May 2004*).

It is clear that the 1997 report is now outmoded with respect to the majority of equipment currently used in the NHSBSP. Therefore, it is important to examine what design changes have been made to mammography equipment since the previous report was published in 1997.

2. ASSESSMENT OF MAMMOGRAPHY UNITS IN CURRENT USE

2.1 Comparison of current units with previous recommendations

The purpose of this section is to compare the recommendations made in the 1997 NHSBSP report with the current ergonomic situation, including assessment both of the units themselves and of their manufacturers' literature. This will indicate areas of the 1997 report that have been acted upon successfully in the design of new units, and also where there are still issues to be addressed.

For the purposes of this work, the following mammographic units have been examined: Alpha RT, GE 800T, GE DMR+, Instrumentarium Diamond, Lorad Mark IV and the Siemens Mammomat 3000. These units include the four most popular models in the NHSBSP (by quite some margin), and together they account for over 95% of the units used in the programme (source: NHSBSP *Equipment Fault Report December 2003 to May 2004*; information taken in July 2004).

The units listed above have all been investigated using the same set of criteria. The recommendations made in the 1997 report highlighted areas where the design of the units could have been improved. Because these recommendations were listed as a means to inform future equipment design, they are being used here as a broad set of criteria to evaluate the current equipment. The design recommendations made in the 1997 report have been included (in italics) as a reference for comparison with current equipment.

2.1.1 Tube head placement

> *When the tube head is rotated (particularly when taking the medio-lateral view), the radiographer has to bend underneath it to view and position the breast. Investigations should be conducted to try to identify different positions of the tube head relative to the breast support table. Possible solution is to have a tube head that 'rotates' away from the C-arm to provide the space for the radiographer to position the breast.*

The **Instrumentarium Diamond** has a 'park away' tube head feature (Figures 1–3). This enables the mammography practitioner to retract the tube head (away from the woman being imaged) to provide extra space for the mammography practitioner to operate. The feature is motorised and operates at the press of a button. This appears to have been intended to be used primarily for stereotactic examinations as it affords both the mammography practitioner and the woman being imaged more space during these examinations (which can be time consuming to prepare). However, the facility could also potentially be used when performing the mediolateral (MLO) view. Therefore, when the unit is rotated to 45° the mammography practitioner has more space around the tube head; however, she would still have to crouch below the tube head when positioning the breast, but this may offer slightly more space.

Although this can be ergonomically useful in some cases, it is not thought to be an ideal solution as the tube head does not retract fully away from the woman, which forces some mammography practitioners to continue to bend beneath the tube head during positioning. This feature could be developed further, however, such that the tube head fully retracts and completely removes the need for mammography practitioners to bend under the tube head.

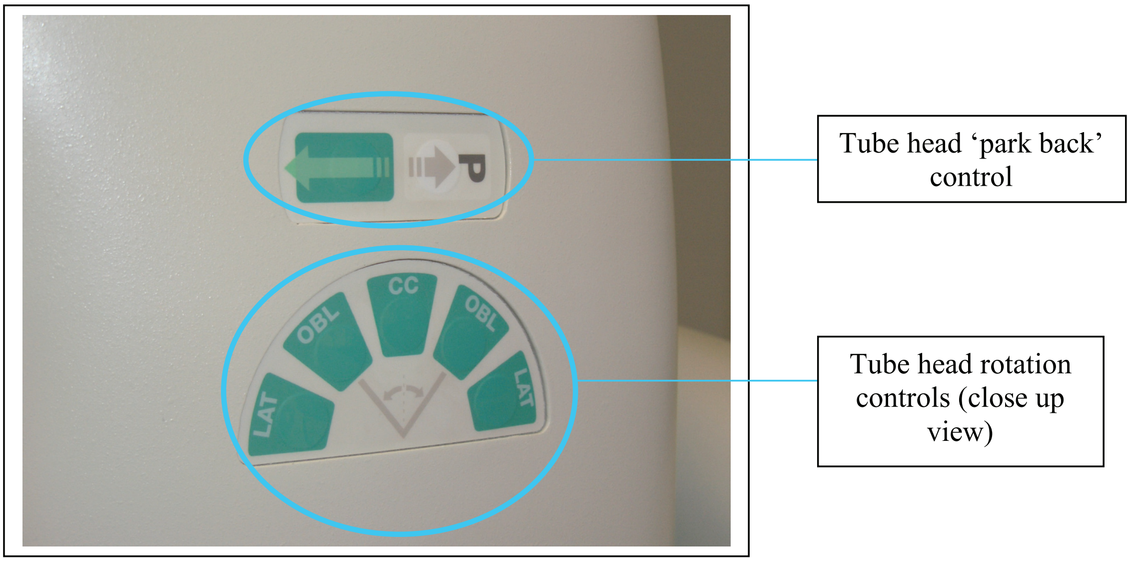


Figure 1 Instrumentarium Diamond showing head parking controls.

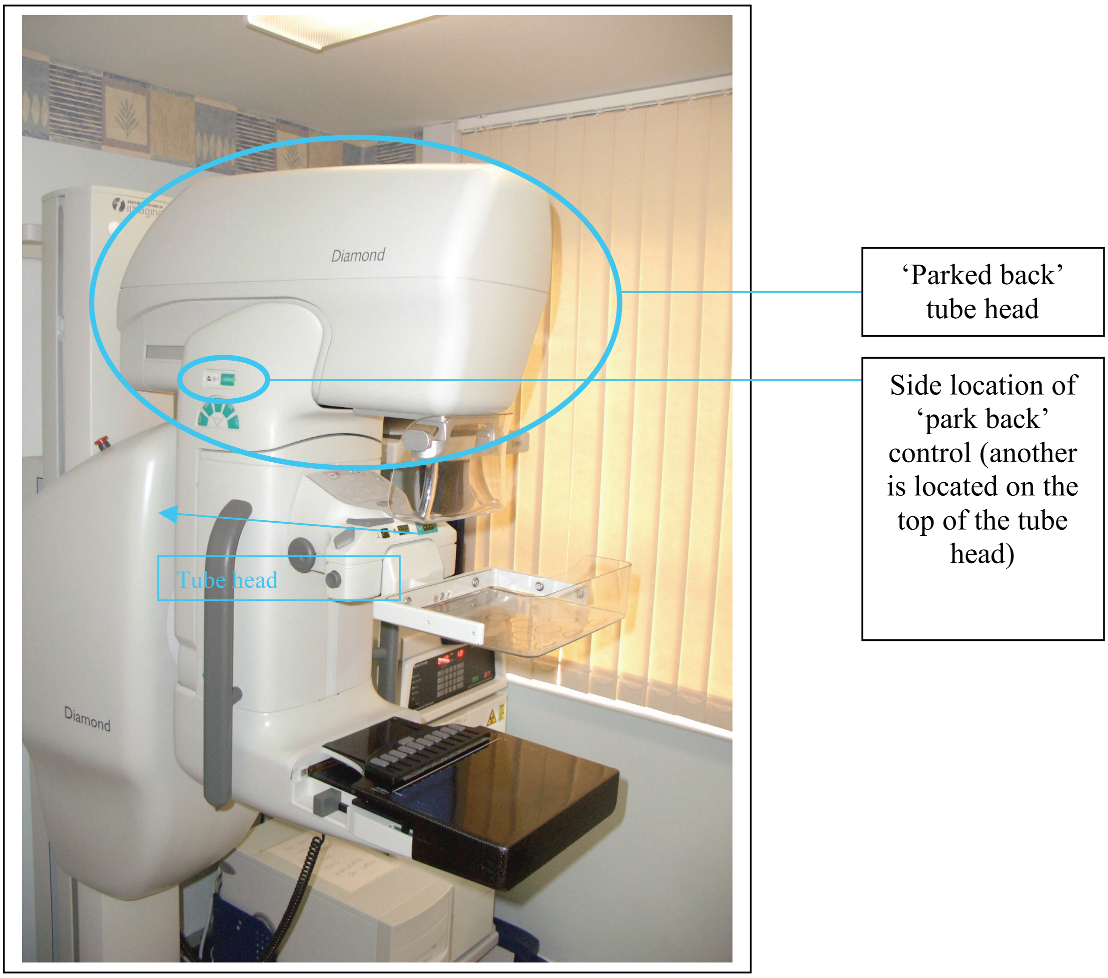


Figure 2 Instrumentarium Diamond showing 'parked' head.

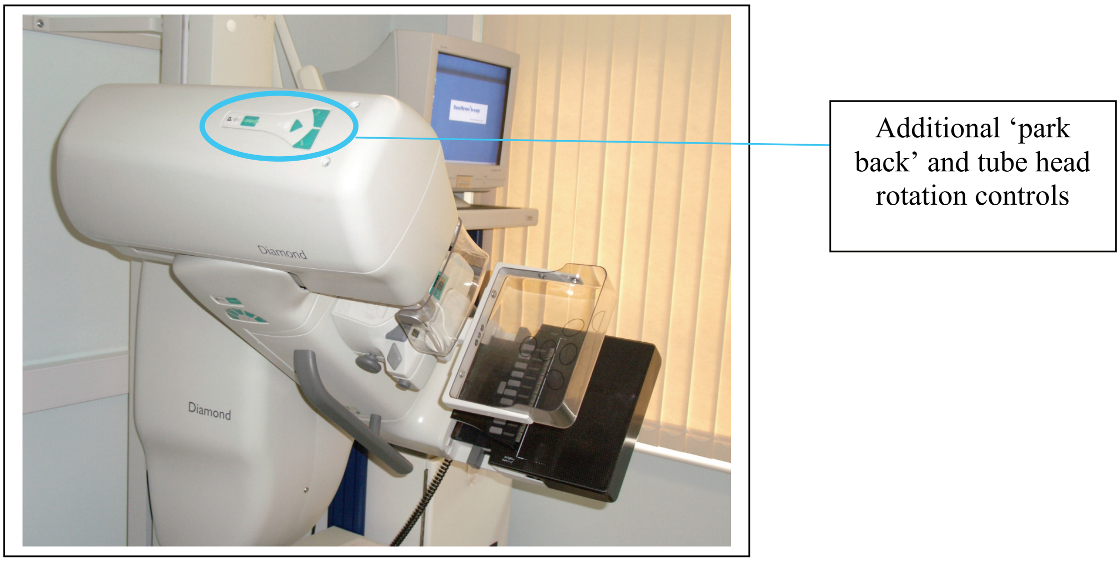


Figure 3 Instrumentarium Diamond showing parked and rotated head.

The 1997 report highlighted this aspect of mammography as being one of the most harmful, particularly for the back and upper limbs. Any feature which reduces the need for mammography practitioners to bend should be welcomed.

None of the other units currently in use incorporates such a facility. All have similar structural features as those units examined in 1997. Although the effects can be minimised by awareness and postural training, this remains an area where mammography equipment design can be radically improved.

2.1.2 Unit controls

Controls should be located in positions where they cannot be accidentally operated, but are within easy reach of the operator such that she does not need to twist to locate and operate these.

A better design was highlighted where controls were located at both the top and bottom of the C-arm (enabling easy operation by all sizes of radiographer). Controls should also be placed on the top of the tube head for easier operation when the lateral view is taken.

Controls should be located towards the front of the tube head to limit the extent of reaching, bending and twisting the radiographer must perform when adjusting the height of the breast support table.

Controls placed on handles should be within easy reach of the position where the radiographer would usually grip the handle. This means that they do not have to stretch and position the hand and wrist awkwardly when gripping the C-arm and operating controls.

Controls should be easily located and be different in position, texture, shape and colour to aid easy identification, preferably without having to be visually detected.

Since the 1997 report, it appears that manufacturers have recognised the need to locate controls within easy reach on the units, thus enabling mammography practitioners of differing sizes to operate them without having to reach or stretch excessively. This is good practice when done effectively, and has been achieved mostly through introducing multiple sets of controls on the units.

Units requiring the mammography practitioner to manually rotate the tube head to the desired angle have the rotation release buttons positioned on the handles. The mammography practitioner depresses the rotation release button and rotates the unit into position with the same hand. The **GE 800T** and the **GE DMR+** both have two sets of controls on the handles, one at the bottom of the handle and one at the top (this allows tall and short mammography practitioners to operate the unit) (Figures 4 and 5). These are positioned towards the ends of the handles, thus giving maximum leverage around the point of rotation of the unit. A concern over locating controls on the handles is that mammography practitioners are forced to deviate the wrists when moving the unit into position. Generally, the handle is gripped and the thumb is used to operate the rotation lock control. When the unit is moved towards the endpoint of the rotation, this involves the wrist being deviated (either ulnar or radial deviation, depending on whether the bottom or top set of controls is used). Excessive and/or repetitive deviation of the wrist, especially when under load, can result in repetitive strain injury (RSI) and work related upper limb disorders (WRULDs).

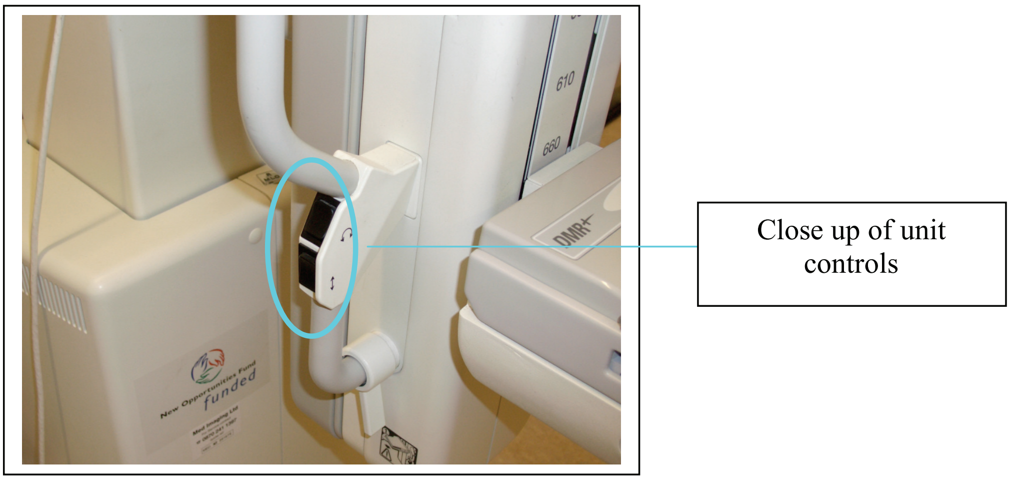


Figure 4 GE DMR+ showing handle controls.

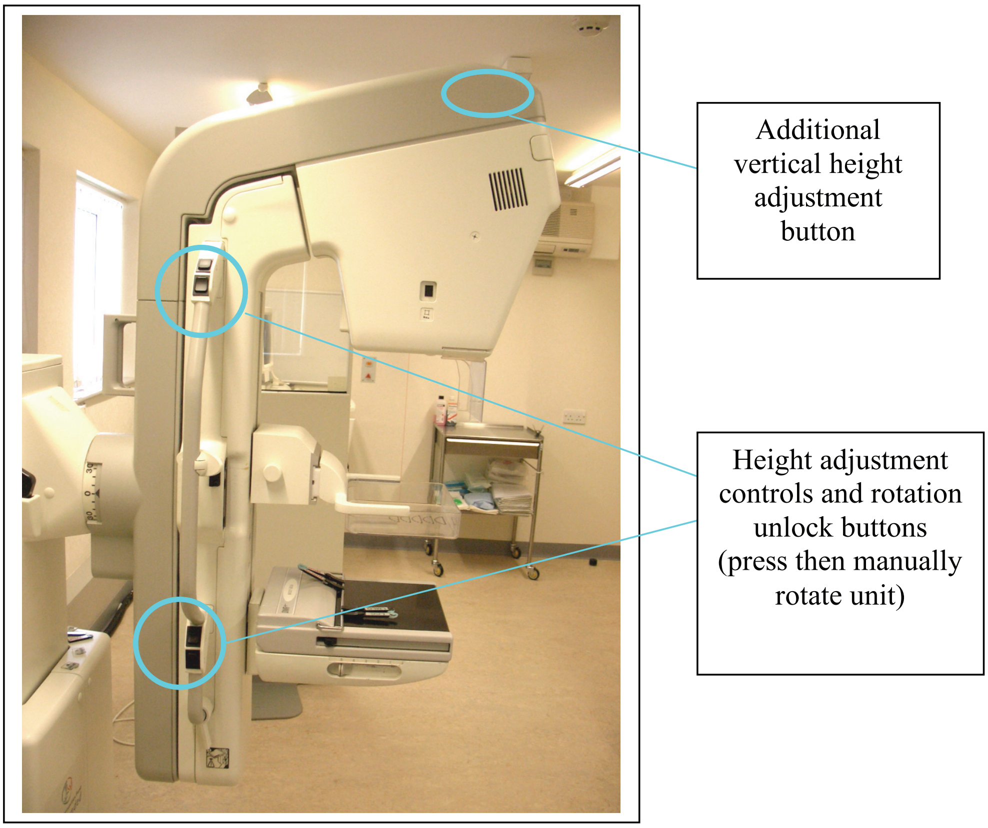


Figure 5 GE DMR+ showing multiple control locations.

The Instrumentarium Alpha RT has three sets of controls on either side of the unit (Figure 6). Two are on the handles that run vertically up the side of the unit; these controls are positioned low and high on the handles. A third control is on the handle that runs horizontally across the top of the tube head; the control is positioned towards the front of the tube head. A fourth control is located on the handle which loops beneath the bucky (Figure 7). This allows shorter staff to rotate the unit into position easily as it affords good leverage. Again, the controls placed on the handles encourage mammography practitioners to deviate their wrists as they rotate the unit into position. When combined with the force the practitioner is using to rotate the unit into position, there is potential for wrist injury to occur. The **Alpha RT** unit is marketed as being light to rotate; however, this is an action performed repetitively throughout the day, and with sufficient repetition and deviation even relatively little force can result in RSIs, so a more complete solution would be preferred.

All these units have motorised height control. The **Alpa RT**, the **GE 800T** and the **GE DMR+** have a control positioned towards the front of the tube head (on the Alpha RT this is positioned on the horizontal handle, and on the GE 800T and GE DMR+ this is positioned separately on the top of the tube head itself) (Figure 8). This allows mammography practitioners to position women into the unit (generally during oblique or lateral views) and make adjustments to the unit height beside the women; they do not have to stretch over to the height adjustment control located towards the rear of the unit on the vertical handle.

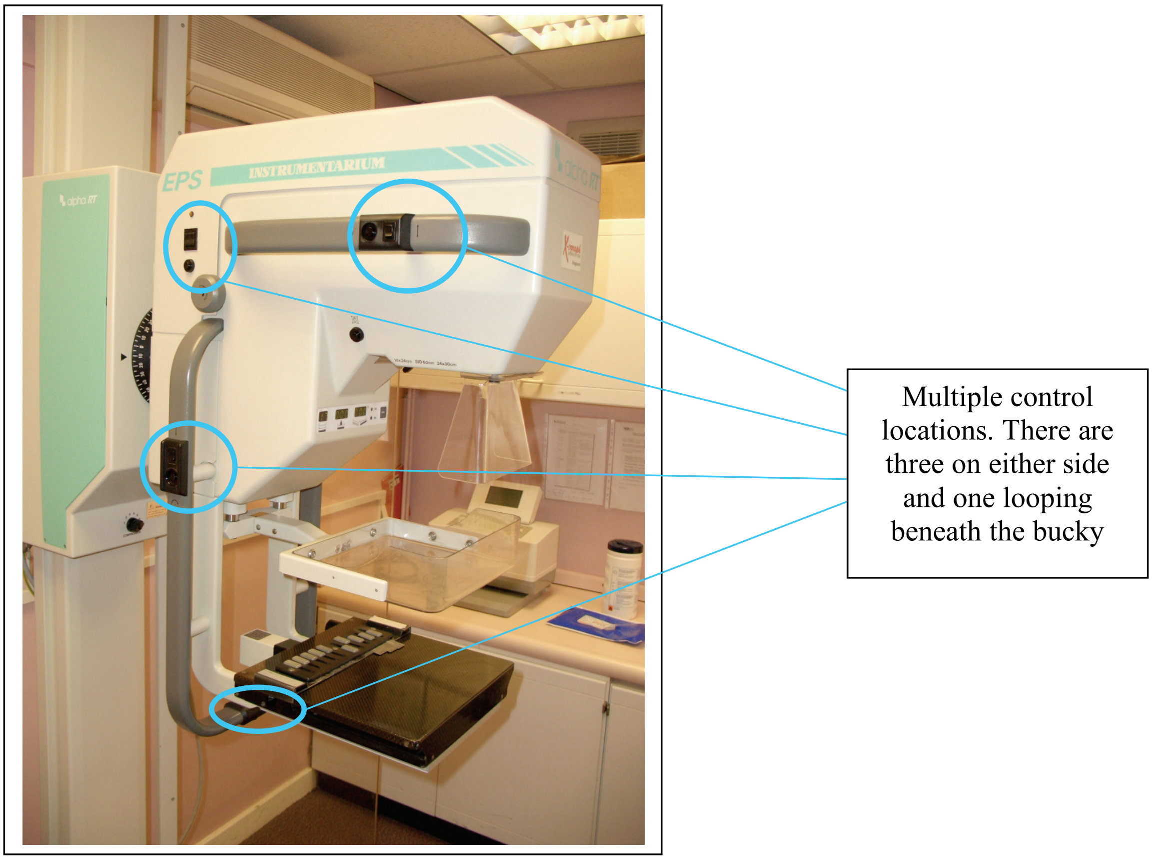


Figure 6 Instrumentarium Alpha RT showing three sets of controls on either side.

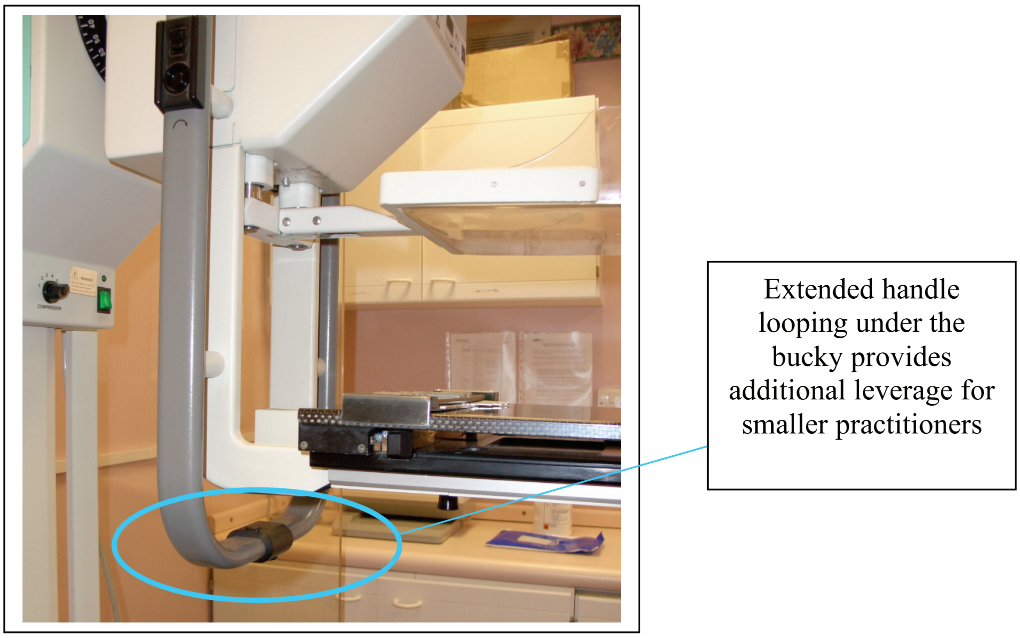


Figure 7 Instrumentarium Alpha RT showing the fourth control beneath the bucky.

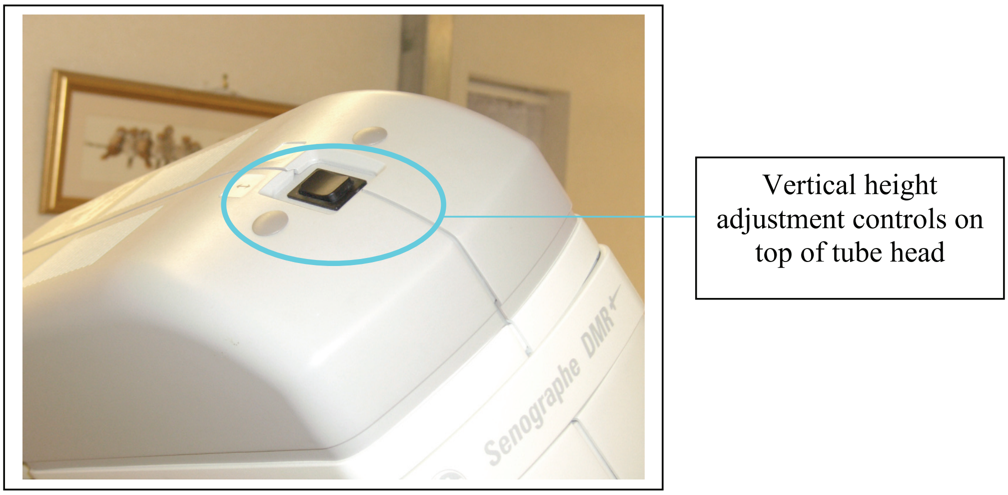


Figure 8 GE DMR+ showing height adjustment controls.

The **Lorad Mark IV**, the **Siemens Mammomat 3000** and the **Instrumentarium Diamond** have fully motorised controls. However, the Lorad Mark IV has only one set of controls either side of the unit and these are positioned towards the top of the tube head. When shorter mammography practitioners screen taller women, they have difficulty stretching to operate the controls. The unit offers other controls towards the back of the C-arm, but these do not control rotation. The extra set of rotation controls is located behind the C-arm, which is not convenient; for some, it is hard to see which button is being pressed and practitioners have to reach behind the C-arm to operate it (Figures 9–11).

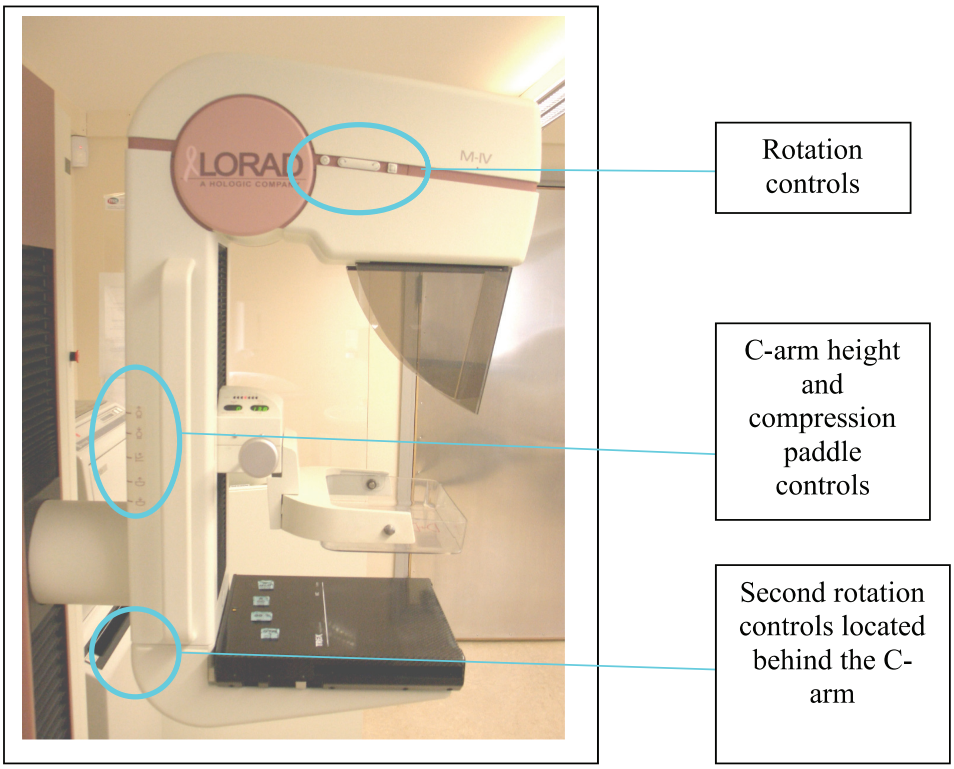


Figure 9 Lorad Mark IV showing controls towards the top of the head and behind the C-arm.

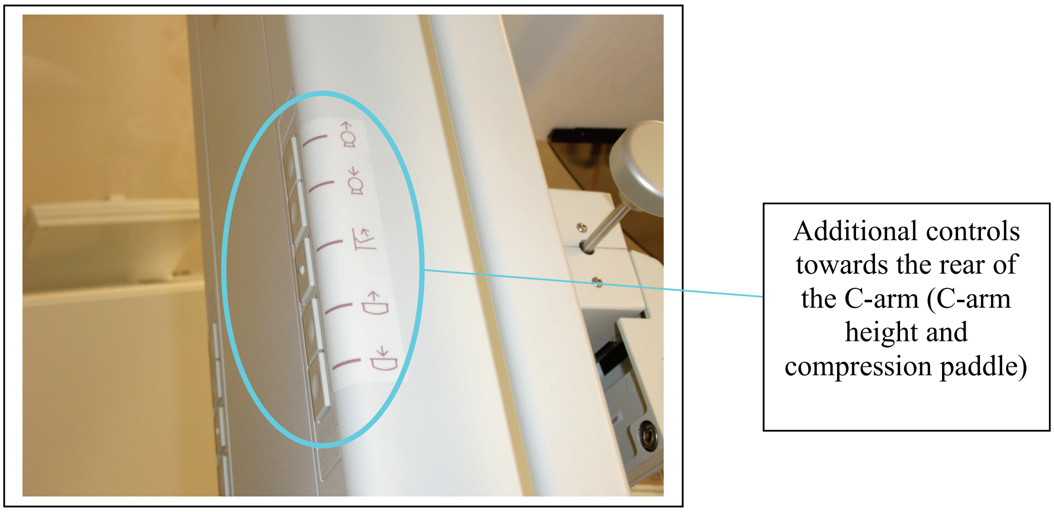


Figure 10 Lorad Mark IV showing additional controls towards the rear of the C-arm.

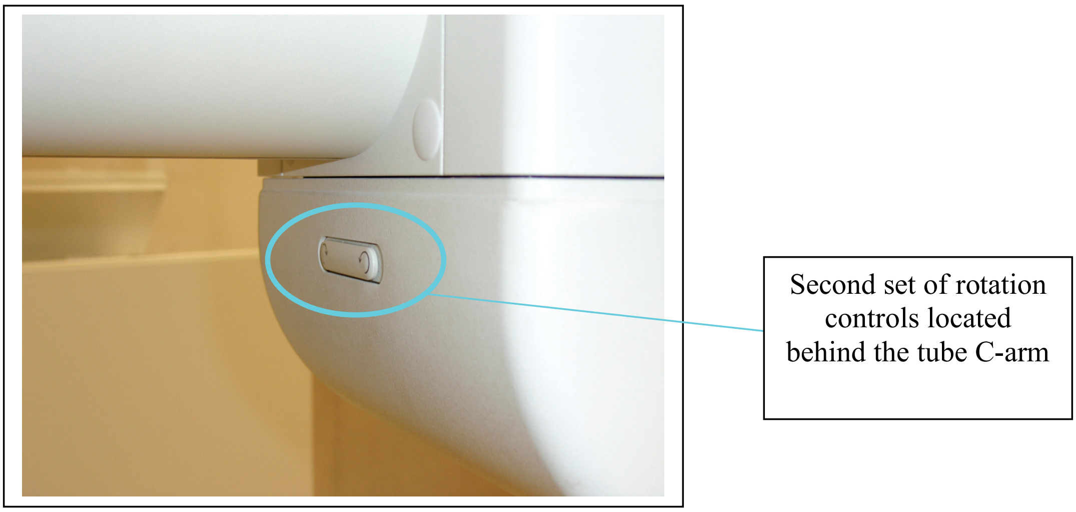


Figure 11 Lorad Mark IV showing the second set of rotation controls.

Although the Siemens and the Lorad rotation is motorised, the mammography practitioner still has to hold the rotation button down while it moves into position, possibly for safety reasons. Therefore, the mammography practitioner is still holding the arm in a static posture (often above shoulder height) for the duration of the rotation and, likewise, when adjusting the height of the tube head. Motorisation can usefully reduce the force that must be exerted by the practitioner, but the act of frequently raising and/or holding the arms in a static posture can also cause WRULDs if the posture adopted itself places sufficient stress upon joints and muscles.

The **Siemens Mammomat 3000** unit has two sets of controls, one on either side of the unit (Figure 12). One is placed towards the rear of the unit and is set low; the other is positioned on top of the tube head at the front. This allows various sizes of mammography practitioner to operate the controls easily and limits any excessive stretching that may be required to operate the unit. The unit 'halts' as it reaches a rotation of 45°; this indicates to the practitioner that the common MLO angle has been reached and takes some emphasis away from the practitioner having to position the unit exactly at this angle. The **Lorad Mark IV** has a similar feature; it also has a 'memory' function whereby the unit automatically halts at the angle just imaged for the second view of the opposite breast.

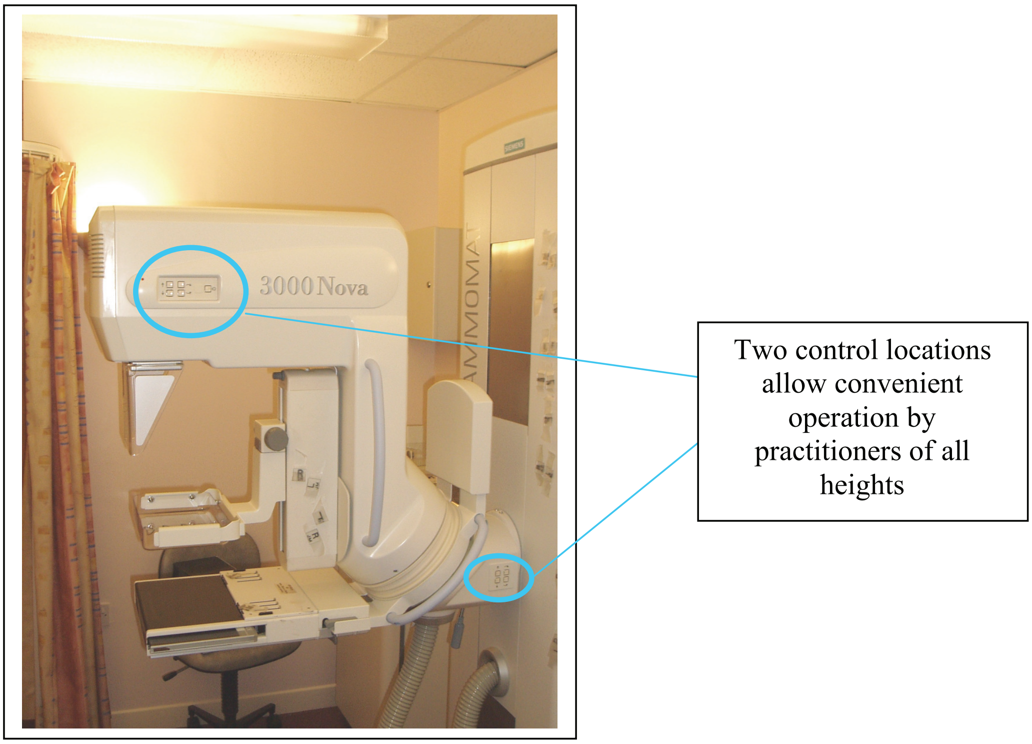


Figure 12 Siemens Mammomat 3000 showing two sets of controls, one on either side.

The Instrumentarium Diamond has one primary set of controls on a 'panel' located just behind the compression paddle (Figure 13).The controls here operate vertical height adjustments, the light beam and the automatic exposure controls (AEC). Placed midway up either side of the unit (towards the rear of the unit) are the oblique and lateral control buttons (Figures 1 and 14). The mammography practitioner selects the position she wants the unit to move to for the following image and the unit moves automatically to the preset angle which is stored in memory. Once the button has been selected, the practitioner taps a control on the foot pedal and the unit moves into position (Figure 15). The advantage this has over the Siemens and Lorad units is that the practitioner does not need to hold the control down during the movement of the unit between angles; she simply selects it and the unit moves into position. This limits the need for static postures and the extent of elevated arm postures adopted by shorter practitioners. Units with the motorised rotation facility vastly reduce the extent of forceful upper limb movements when mammography practitioners manoeuvre the unit into position between the views.

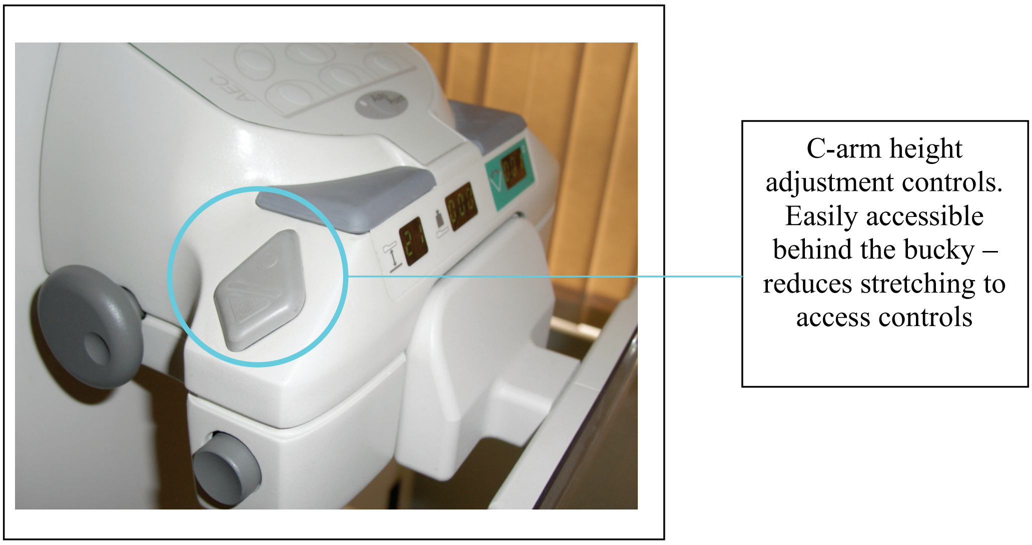


Figure 13 Instrumentarium Diamond showing controls behind the paddle.

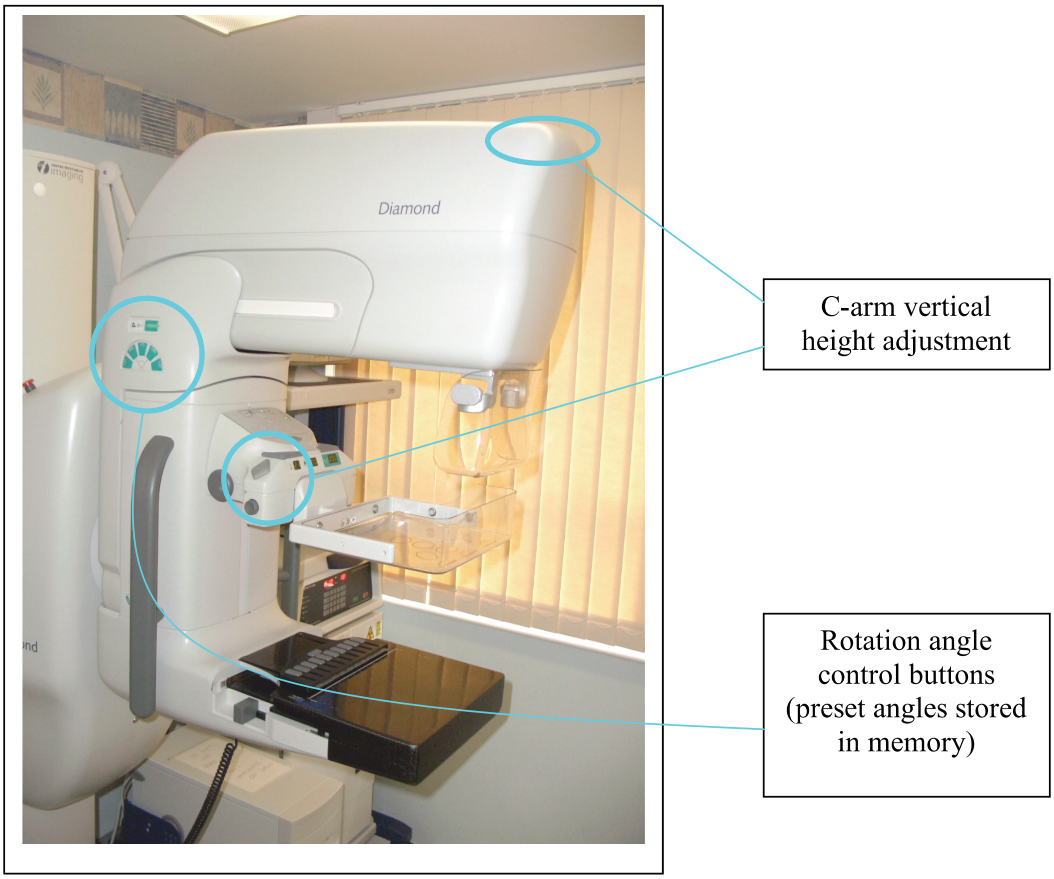


Figure 14 Instrumentarium Diamond showing controls.

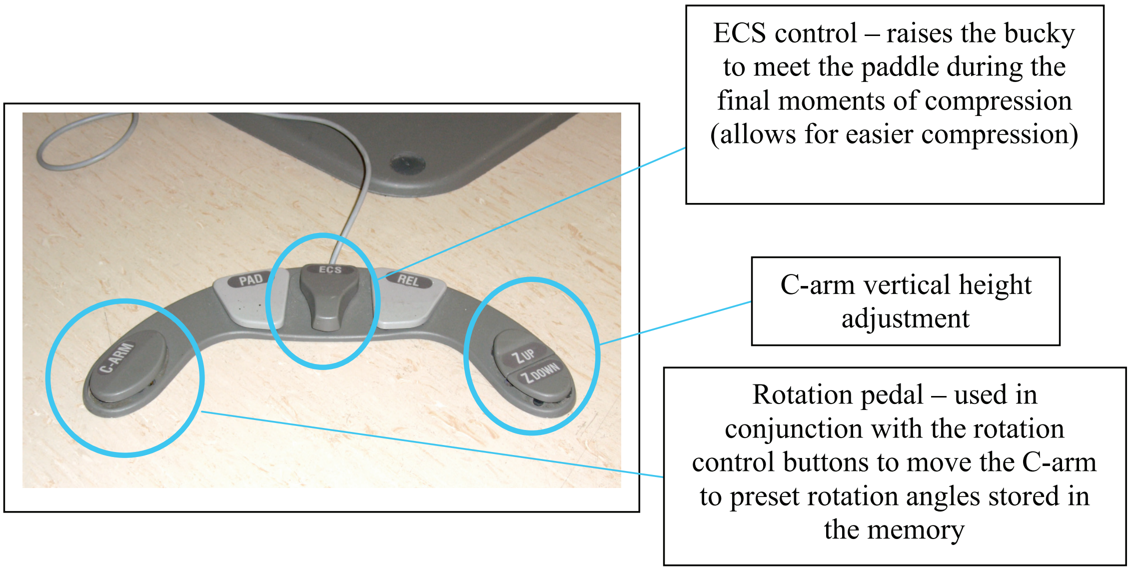


Figure 15 Instrumentarium Diamond showing the foot panel.

Accidental operation of the controls has been reported on the **Lorad Mark IV** when taking the lateral oblique views. The control is not recessed into the unit and when the mammography practitioner is bending beneath the tube head, positioning the breast, it is possible that she could touch the controls. All other units have controls either recessed or in positions not directly likely to be touched by the practitioner during positioning. The units with controls on the handles will be accidentally operated only if the woman being screened inadvertently holds on to them. Mammography practitioners give very clear instructions to the women that they should hold the handles away from the controls at all times; however, this can be quite a stressful situation for the client and it can reasonably be expected that there will be varying degrees of compliance and understanding in a group as wide ranging as the screening programme client base.

2.1.3 Light beam switch

This should be located on both sides of the tube head rather than underneath it; this allows it to be easily located by either hand from both sides of the unit.

It should be an option that this can be operated by a control on the foot pedal.

The length of time the light remains illuminated should be at variable settings to suit each individual radiographer.

There are clear design differences with regards to the location of the switch across the units examined. On the **GE DMR+** the switch is located at the rear of the tube head, making it awkward for mammography practitioners to locate and use when positioning the woman (Figure 16).‘Cone’ buttons are located at the sides of the unit; these are used to vary the area over which the radiation falls on the bucky. The ‘cone’ buttons are used infrequently, however, and it would seem more appropriate to locate the more frequently used light beam switch in this more accessible location.

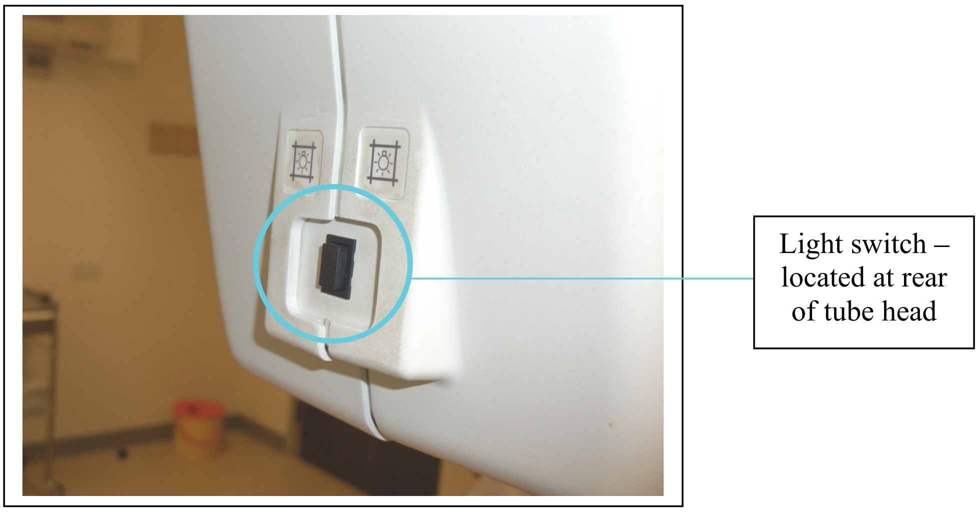


Figure 16 GE DMR+ showing the light switch.

The GE 800T has the light switch located next to the movement (rotation and height) controls. Therefore, this is easy to locate. On the **Alpha RT** the switches are located midway up both sides of the unit and are convenient for most mammography practitioners to operate. Similarly, the **Lorad Mark IV** has the light beam switch located next to the single set of rotation controls on the side of the tube head. However, these may not be as convenient for shorter practitioners to operate because the controls are positioned at the top of the tube head. The **Siemens Mammomat 3000** unit has the light beam switch located next to both sets of controls on either side of the unit – again convenient to locate. On the **Instrumentarium Diamond** the light beam switch is located on the main control panel behind the bucky. This is possibly the most convenient location for the switch as it is directly adjacent to the point where the practitioner is positioning the breast and means the practitioner has to move only a short distance to operate it.

On all units, the light beam operates automatically as soon as compression is applied by the foot pedal. This allows mammography practitioners to operate the light 'hands free'. If compression is halted and the light switches off, the practitioner needs only to tap the compression foot control again and it will turn the light back on. If mammography practitioners have this option of both a conveniently located light beam switch and the foot pedal operated light activation, they have as much freedom as possible to perform mammography variably and flexibly, without being constrained as to which control options to use. Such flexibility is welcomed as not all women can be screened in identical ways.

2.1.4 Exposure button

> *If a push button is used to operate the exposure it should be located centrally so either hand can operate it. This is a repetitively performed operation, a better design would possibly be a control which could be operated by the whole palm – thus distributing the force more widely and making it less focused on particular fingers.*

The **Lorad Mark IV** and the **Siemens Mammomat 3000** have two exposure buttons that must be pressed in unison for the unit to take an image (Figure 17 and 18). The buttons are positioned on either side of the control panel (which is situated to encourage mammography practitioners to stand directly behind the protective lead glass screen) and are, therefore, operated with both hands. The design of the buttons is such that practitioners generally use their fingers to operate them because the buttons do not really protrude far enough from the panel to allow them to be pressed by the palms, which would distribute the pressure more widely.

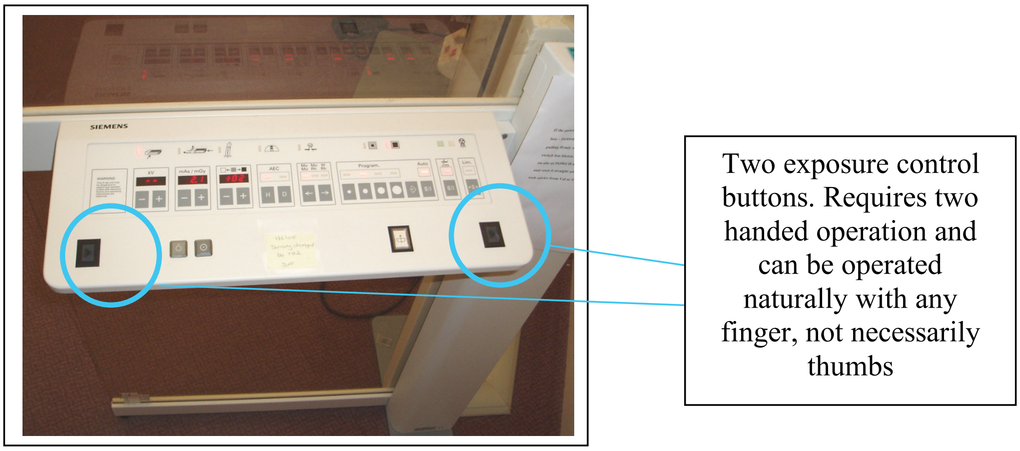


Figure 17 Siemens Mammomat 3000 showing synchronous exposure buttons.

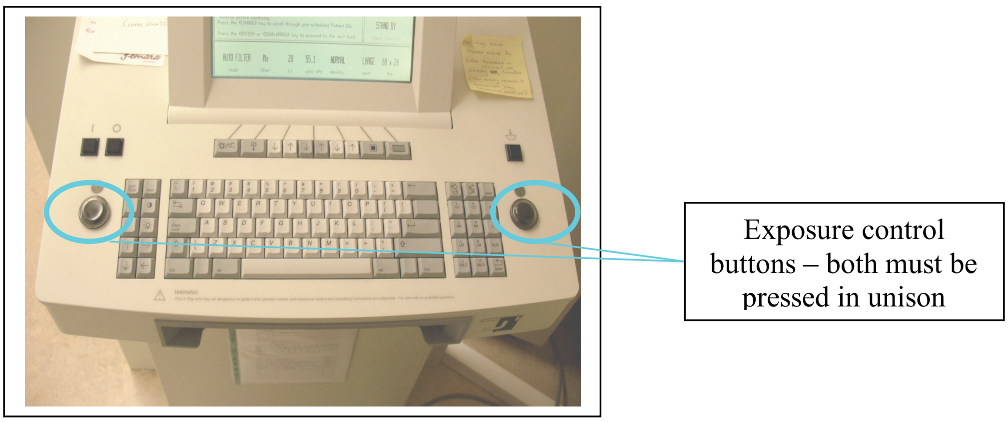


Figure 18 Lorad Mark IV showing synchronous exposure buttons.

The GE DMR+ and the **GE 800T** also have two button operation; however, these buttons are placed directly beside one another. Mammography practitioners can use either two hands to operate these or just one (Figure 19 and 20). Figures 19 and 20 actually demonstrate a unit which has had a secondary exposure control that has been retro-fitted.

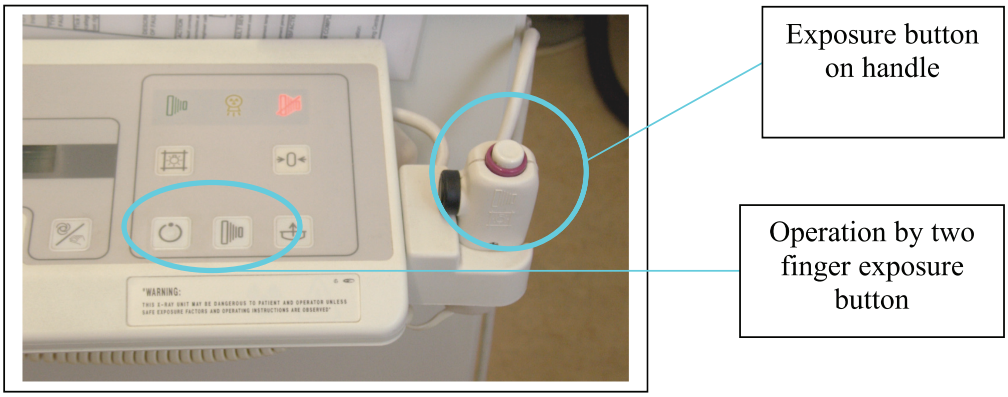


Figure 19 GE DMR+ showing the dual buttons in close proximity.

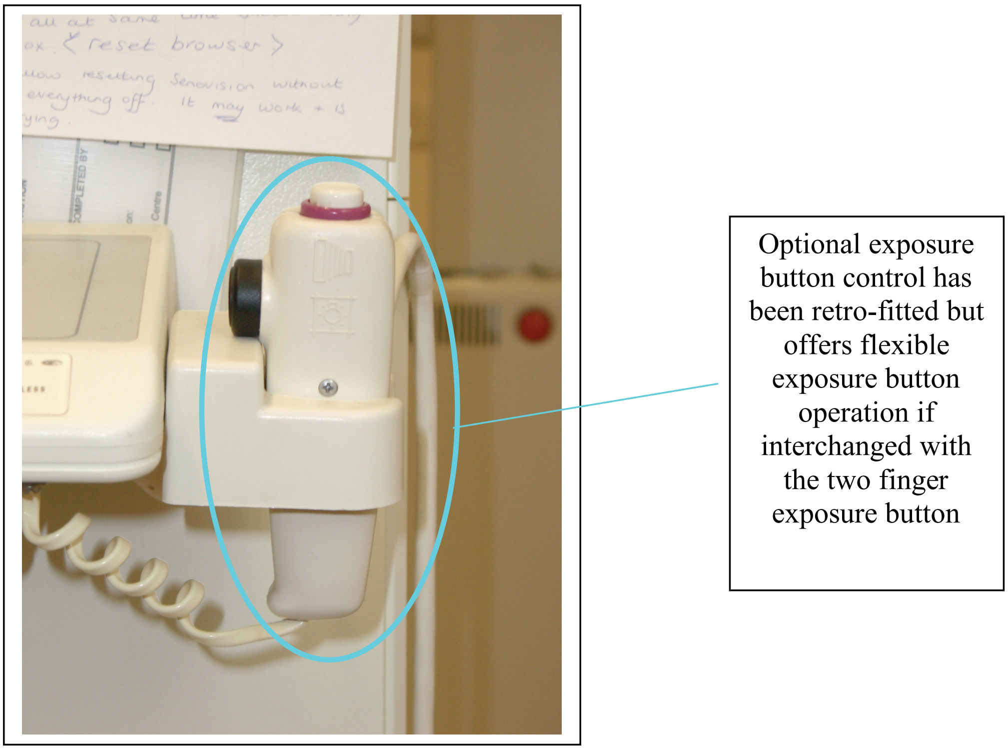


Figure 20 GE DMR+ showing the optional exposure button fitted.

This is much like the **Alpha RT** exposure control. The design requires that the fingers are used to depress the controls. The Alpha RT has a thumb operated, grip hold exposure control (Figure 21). The mammography practitioner has to hold the control and extend the thumb over the top to depress the button – much like a computer joystick. If this control is located conveniently, practitioners do not have to lift the stalk; instead, they simply press the exposure button on the top. This allows variable use by any finger and takes the emphasis away from operation by the thumb.

The **Instrumentarium Diamond** has a single exposure button (the one viewed was wall mounted); the fingers are used to operate this (Figures 22 and 23).

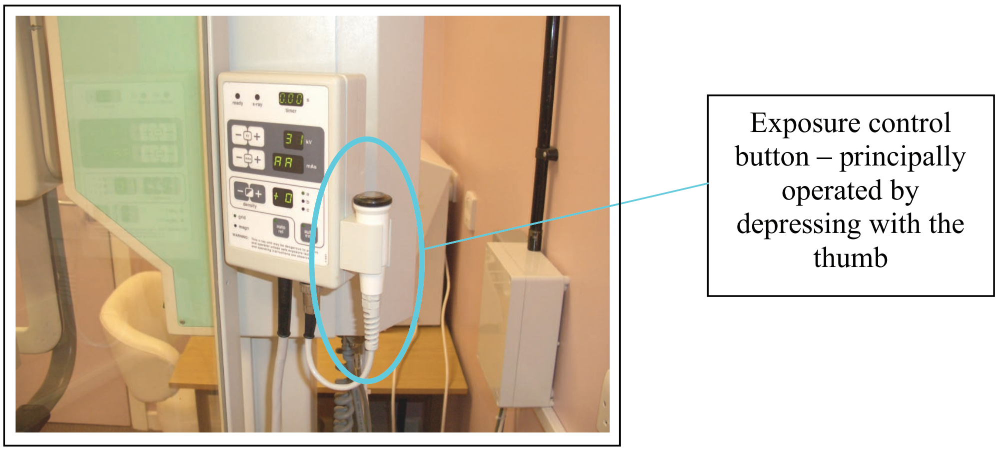


Figure 21 Alpha RT showing the exposure control button.

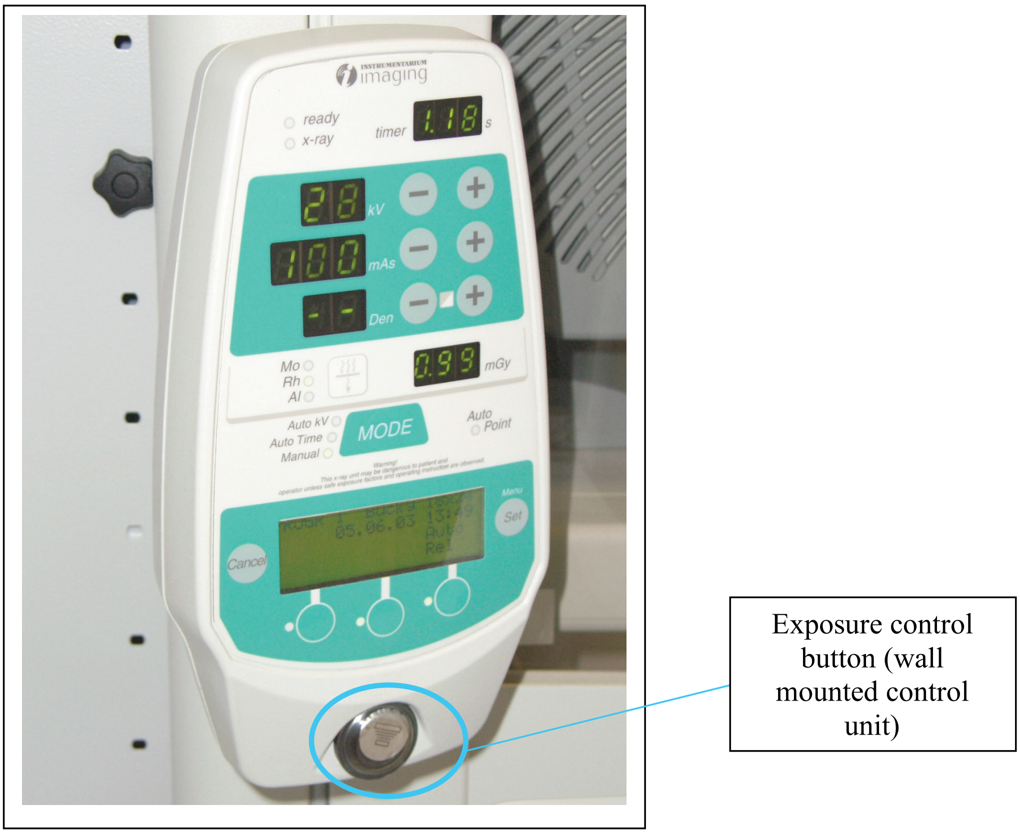


Figure 22 Instrumentarium Diamond showing the single exposure button.

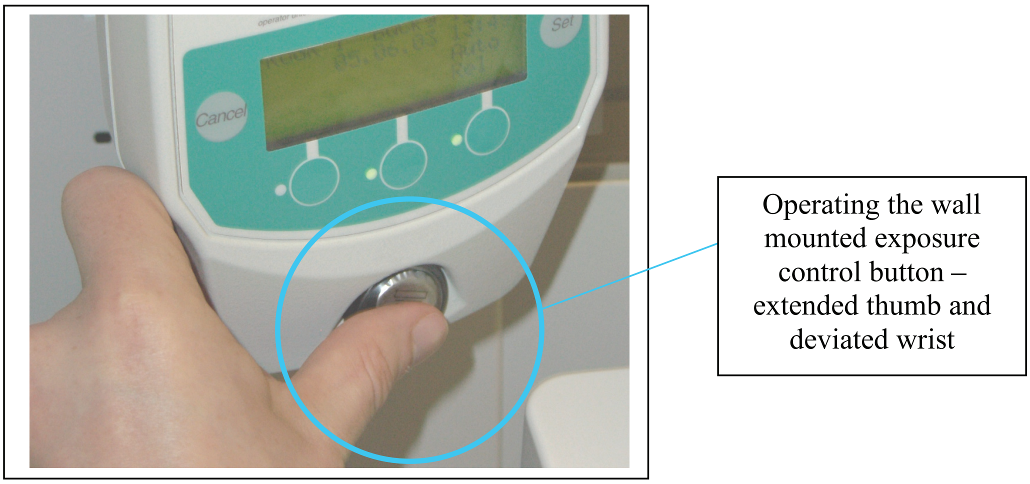


Figure 23 Instrumentarium Diamond showing the extended thumb and wrist.

None of the units observed had a palm operated exposure button. The **Siemens Mammomat 3000** and the **Lorad Mark IV** give the greatest potential for mammography practitioners to operate the exposure control variably by changing the finger they use to operate the exposure. This limits the repetition with which a single finger operates the control.

2.1.5 Application of final compression

The compression plate must be power driven in both directions of travel over the complete range of movement.

All units have power driven compression, controlled by foot pedals. The units also have a dial which can be manually rotated to apply slight increments to compression/final compression. Mammography practitioners have complained that the **Instrumentarium Alpha RT** and the **GE 800T** do not have entirely smooth or responsive compression. The Alpha RT was described as having 'jerky' compression. Practitioners found it difficult to make slight adjustments. It is important that compression is responsive when making these fine adjustments because it allows the practitioner to meet the final compression 'target' quickly and easily. Non-responsive compression requires the practitioner to make subsequent readjustments; this potentially places strain on the feet and ankles when using the compression foot pedal and also slows down the screening process. On the GE 800T, the non-responsive compression is believed to be caused by a poor fitting compression paddle, which was not stable during the application of final compression.

The use of the manual dial should be limited as this requires the practitioner to pronate–supinate the wrist when twisting; this places more strain on the musculoskeletal structures of the wrist.

Several of the units feature an automatic compression release system in which the unit immediately releases compression after the image has been taken. This reduces the need for the mammography practitioner to worry about releasing compression after the exposure and is also more comfortable for the woman being imaged as compression ceases as soon as possible.

The **Instrumentarium Diamond** also incorporates an ECS (Easy Compression System) facility (Figure 15). The mammography practitioner presses the ECS pedal on the foot controls and this moves the bucky upwards slightly to meet the compression paddle as it lowers. This serves to bring the breast over the bucky more effectively, positioning it more positively and reducing the extent of hand and wrist activity required during positioning. A similar feature, the EPS (Ekland Positioning Systen) pedal, is present on the **Alpha RT** (Figure 24).

The paddle depth on the **GE 800T** is considered to be too shallow. This protrudes into the chest wall of the woman during compression, making the experience far more painful. Mammography practitioners have also described situations in which the breast that is not being imaged (the non-compressed breast) encroaches over the shallow lip of the paddle, obscuring the image which is being taken of the other, compressed breast.

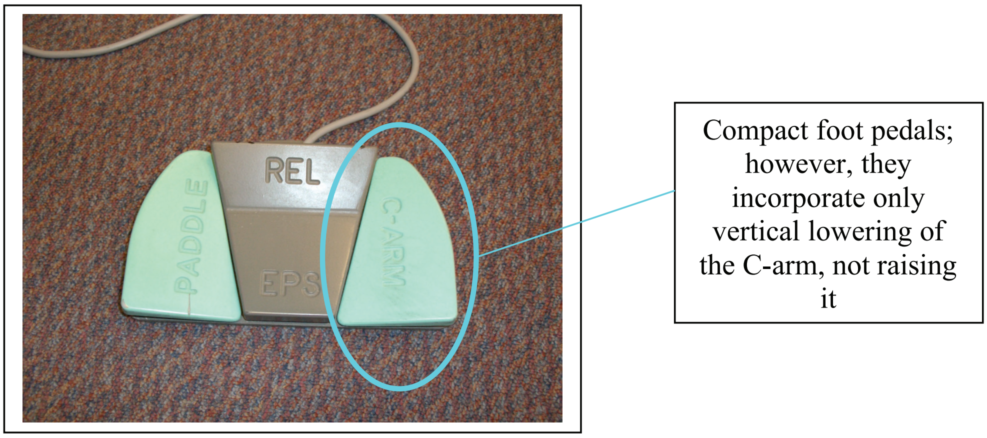


Figure 24 Alpha RT showing the EPS pedal.

2.1.6 Pedals

> *These should be as low as possible and angled slightly to prevent over-flexion and extension of the ankle during operation. The pedal surface should be large enough to ensure that the foot can apply force effectively, but not so large that the pedal becomes a tripping hazard. It should have an area where the radiographer can rest her foot without having to remove her foot from the pedal. Pedals should not be too heavy or cumbersome so they can be easily repositioned by foot around the mammography unit. The lead connecting the pedals to the unit should be of an appropriate length that allows the radiographer to position them to suit her body size and eliminates excessive stretching to operate.*

The design of the foot pedals differs radically from one unit to the next. The **GE 800T** has a small set of pedals. These are low set, lightweight and small, which limits ankle flexion during operation and makes them easy to reposition around the unit. These pedals control only compression, not vertical movement of the tube head. There is a raised lip separating the compression application and release pedals that can act as a foot rest.

Newer models of the **GE DMR+** have more cumbersome foot pedals (Figure 25). However, these pedals also control vertical height adjustment of the tube head. This extra set of controls on the foot pedals often requires mammography practitioners to visually locate the exact pedal function they require. Not all practitioners appreciate or utilise the vertical control adjustment pedals. However, this does reduce the need to continually use the hand controls to adjust vertical column height. The fact that mammography practitioners are given the option of hand and foot controls means that they can choose and, more importantly, vary how they use the machine, and they can use this flexibility to suit the individual they are screening. Any design feature which encourages different methods of operation, and therefore allows the user to limit the extent of repetitive control actions, should be encouraged.

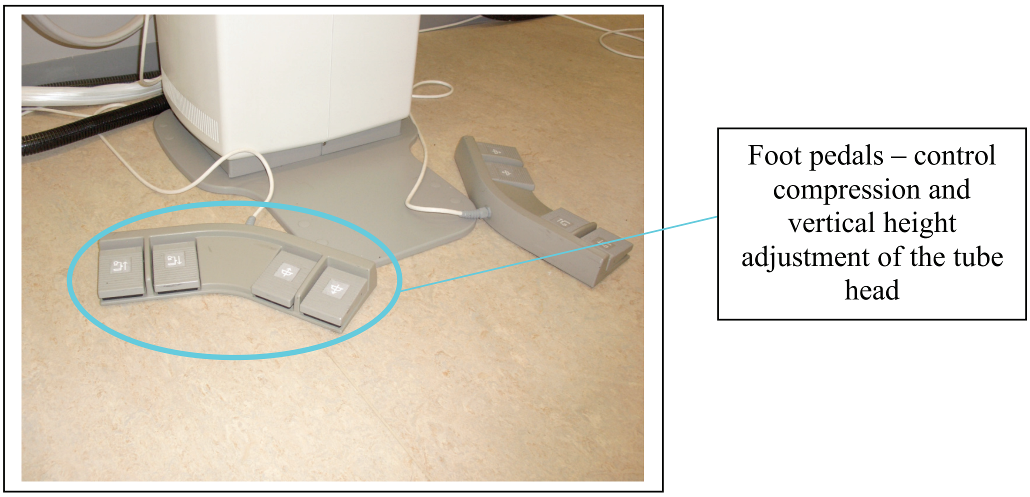


Figure 25 GE DMR+ showing the foot pedals.

The **Lorad Mark IV** has compression and vertical tube head height controls. The pedals are not considered cumbersome and are set low to the floor; there is also a rest area for the foot (Figure 26).

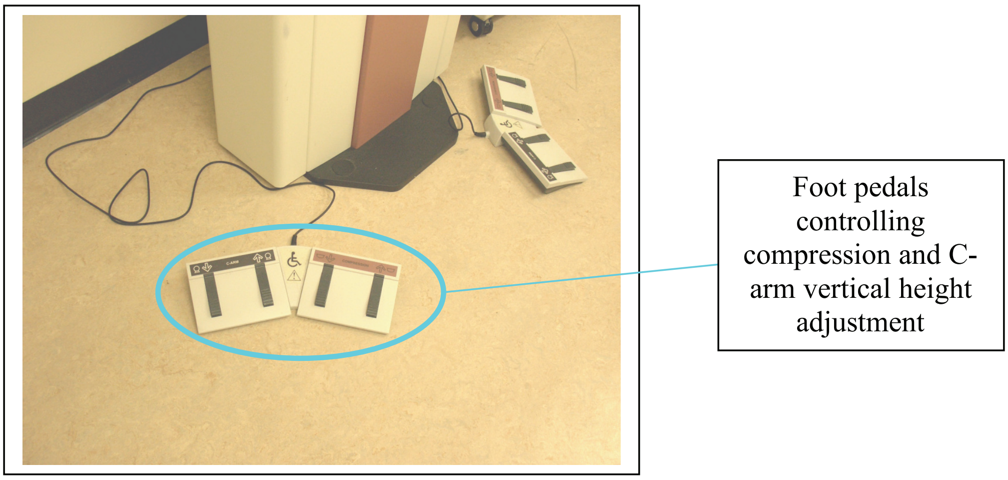


Figure 26 Lorad Mark IV showing the foot pedals.

The **Siemens Mammomat 3000** has no vertical height adjustment control. The pedals are raised from the floor so that the mammography practitioner has to flex the foot slightly to operate them (Figure 27). There is a raised flat platform which separates the pedals and acts as a rest point for the foot.

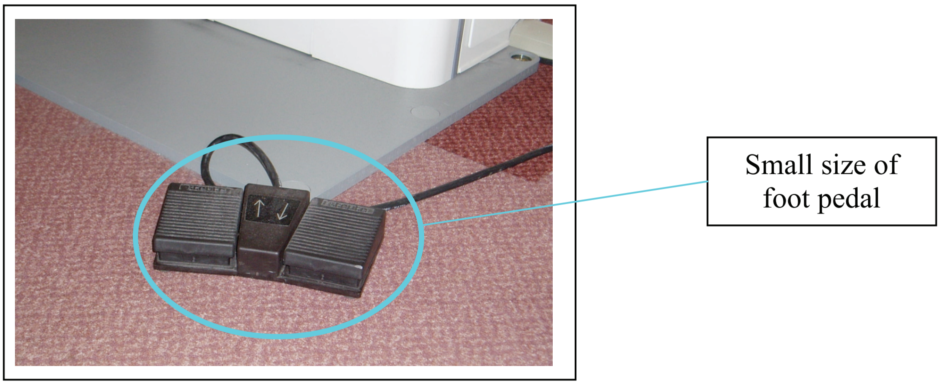


Figure 27 Siemens Mammomat 3000 showing the foot pedals.

The **Instrumentarium Alpha RT** also has compact foot pedals (Figure 24). There are four controls: compression application and release, EPS and vertical tube head lowering (not raising). All controls are close to one another, which means the mammography practitioner does not have to deviate the ankle far to the side in order to operate a particular control. However, there is no rest area, and when practitioners wish to operate the pedal on the far side of the pedal unit they have to raise their ankle from the floor and extend their foot over the control.

The **Instrumentarium Diamond** has a very flat set of foot controls that require minimum flexion of the ankle to operate (Figure 15). The pedal control itself is large, housing six functions (compression application and release, vertical lowering and raising, ECS and the automatic rotation control). These are spaced such that the mammography practitioner must actively move the foot between the controls, essentially deviating the foot, as the controls are spread over a large area. There are adequate rest areas on the foot control, and as such the potential for accidental operation of neighbouring foot pedals is limited. As may be expected, however, this is one of the most cumbersome controls to reposition around the unit.

One mammography practitioner suggested that if the controls were laid out in a mirror image they may be simpler to use. For example, the top grid (see below) shows a mirror image arrangement of the two sets of pedals positioned on either side of the unit (the black box in the centre represents the mammography unit); pedals closest to the unit are identical in function and this pattern continues across the four different controls on either side of the mammography unit. The possible argument is that practitioners can orient themselves better with this arrangement when they transfer around the woman being imaged and around the unit itself. The second grid shows how pedals are arranged at present across all equipment reviewed**. NOTE that this is not a recommendation** – simply a report of one individual's opinion.

Compression on	Compression off	Raise	Lower		Lower	Raise	Compression off	Compression on

Compression on	Compression off	Raise	Lower		Compression on	Compression off	Raise	Lower

Suggested layout (top) and current layout (bottom).

2.1.7 Unit handles

Handles should be rounded so the corners do not 'dig' into the hands when gripped. They should be textured with material that does not feel cold to the touch (ie non-metallic) and is not slippery when gripped. The location of the handles should not restrict the radiographer's access to the woman during positioning and they should run the length of the C-arm (past the pivot point). This enables all sizes of radiographer to easily reach them above or below the pivot such that they gain a mechanical advantage when rotating the C-arm. Handles should be colour coded to distinguish the handles to be held by the radiographer from those to be held by the woman. This makes it easier for the radiographer to instruct the woman to hold a certain handle.

All units that are manually rotated into position have adequate handles which run the entire length (vertically) of the mammography unit. This provides both tall and short mammography practitioners with adequate leverage when rotating the unit. The motorised units, ie the **Siemens Mammomat 3000**, **Lorad Mark IV** and the **Instrumentarium Diamond**, do not require handles like this as they move into position without any forceful exertion by the practitioner. All handles are smooth and non-metallic and are coated in non-slip material.

On the **Instrumentarium Alpha RT** there is a second handle running horizontally across the top of the tube head (Figure 28). Although this provides mammography practitioners with a further point of leverage when moving the unit into position, the handle protrudes several inches on either side of the tube head. When taking the oblique views, this reduces even further the space around the tube head (ie when the practitioner has to position the breast by bending under the tube head, which is rotated 45°). If the handle running vertically along the rear of the unit (Figure 6) was extended further (to the top of the tube head), it would provide similar leverage to the horizontal handle. This would enable the horizontal handle to be removed and would provide more space around the unit. Mammography practitioners would then simply use the sole vertical handle, as they are required to do on the other units which are rotated manually.

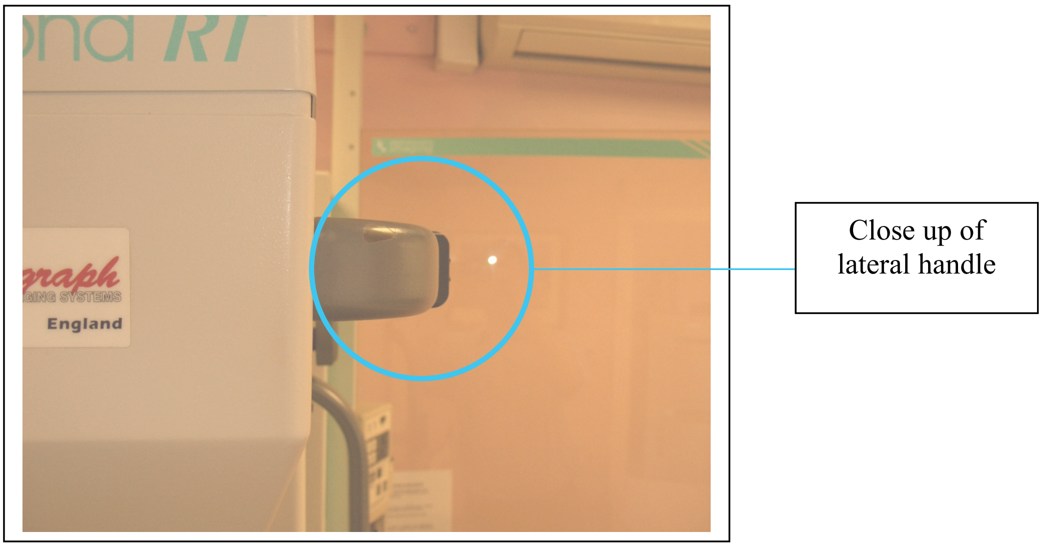


Figure 28 Instrumentarium Alpha RT showing the lateral handle.

2.1.8 Inserting and removing the film cassette from the breast support table

When inserting and removing the film cassette to/from the breast support table the radiographers often extended their thumbs or fingers while applying pressure to the cassette or button to release it. Force was also applied and the wrist was deviated. This problem could possibly be alleviated by rollers which feed the cassette in and out of the breast support table. However, this may take longer to perform.

All units feature two handed cassette release with a slide mechanism at the side of the bucky. To release the cassette, mammography practitioners have to slide the catch at the side of the bucky (this is generally done with the thumbs extended; Figure 29); they then have to reach over the bucky with the other hand and flex their fingers into the cassette loading recess to push out the cassette. Next, they pinch grip the cassette to remove it from the bucky. The **Lorad Mark IV** and some models of the **Siemens Mammomat 3000** automatically 'eject' the cassette once the slide catch at the side has been released, thus eliminating the need to push out the cassette manually.

This sliding release mechanism increases the strain on the thumbs and fingers during the screening process. The same release mechanism has been in use since the 1997 report, and it was highlighted then how potentially harmful this design was. Thumb pain is one area highlighted by mammography practitioners, and equipment needs to be designed that reduces forceful use of the thumb during the screening process.

The **Instrumentarium Diamond** has an automatic loading facility, in which the loaded cassette is drawn into its final position mechanically. However, the cassette must still be removed as explained above. There needs to be more ergonomic design incorporated into the development of the loading–unloading systems.

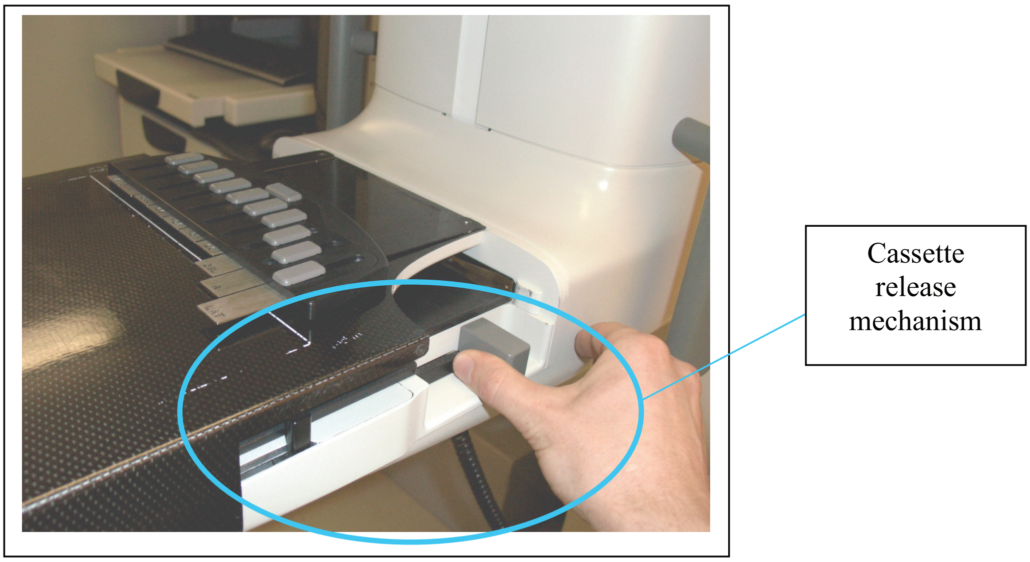


Figure 29 Instrumentarium Diamond cassette showing the release mechanism.

2.1.9 Rotation guideline and compression displays

> *The rotation guideline should be located so that the radiographer does not have to twist to visualise it. The guideline should always be visible from the position the radiographer adopts during positioning of the woman. It should not be obscured by any parts of the unit.*
>
> *All digital displays should be easily visible in the lighting conditions of the room.*
>
> *When performing the medio-lateral view the angle of 45° forms the basis from which all minor adjustments are made. This angle should be clearly distinguishable from all other markings on the scale.*

The layout and location of these displays vary greatly across all units. Not all are in positions that are easy to visualise, and it appears that not all manufacturers have accepted the need to design displays that can be viewed easily by all sizes of mammography practitioner, no matter their orientation around the mammography unit.

The **Lorad Mark IV** has a compression display which is located several inches above the height of the bucky (attached to the compression paddle) and is angled upwards (Figure 30). This makes it difficult for shorter mammography practitioners to visualise the display when preparing for the craniocaudal (CC) view (particularly when the woman being imaged is tall). There are two rotation guideline displays that are positioned behind the C-arm (one on either side of the tube head). However, these can be obscured by the C-arm when the unit is rotated to certain angles. It is unacceptable that mammography practitioners have to bend and twist around the C-arm to view the angle of rotation when it is this information that they require to rotate the arm to its endpoint.

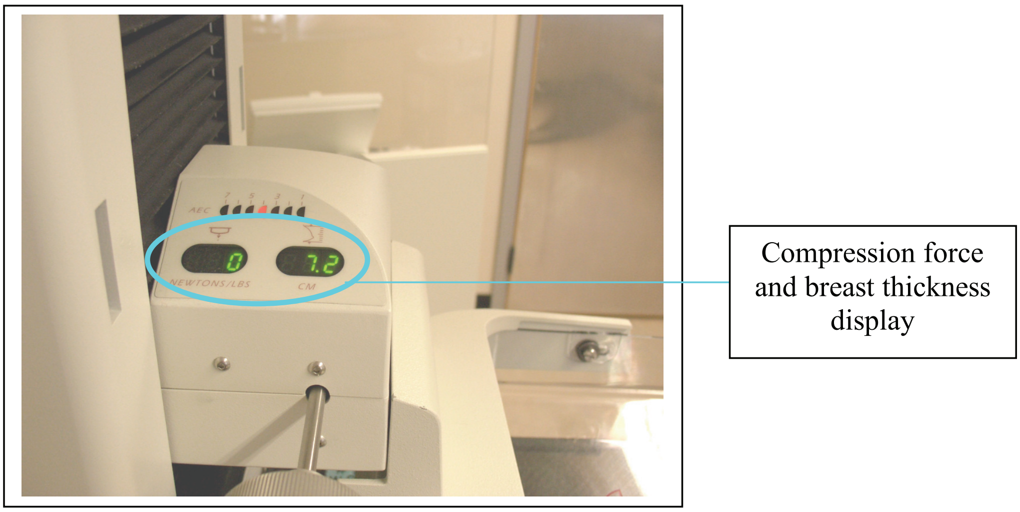


Figure 30 Lorad Mark IV showing the compression display.

On the **GE 800T** and the **Siemens Mammomat 3000** the compression and rotation display is located at floor level on the base of the support column (Figures 31 and 32). This is angled upwards. This location of the digital display is considered to be adequate as the mammography practitioner is, generally, already looking downward when positioning the breast on the bucky. If the display is below the bucky, but still in the line of sight, mammography practitioners do not have to twist away from the area they are concentrating on to view the compression information. It could be argued that they are being forced to flex their necks for a longer period of time than necessary when finalising the rotation information (prior to applying compression) because they have to look towards the floor to get the digital feedback. If there was a second display higher on the unit, it would allow practitioners to view whichever display was more comfortable for them.

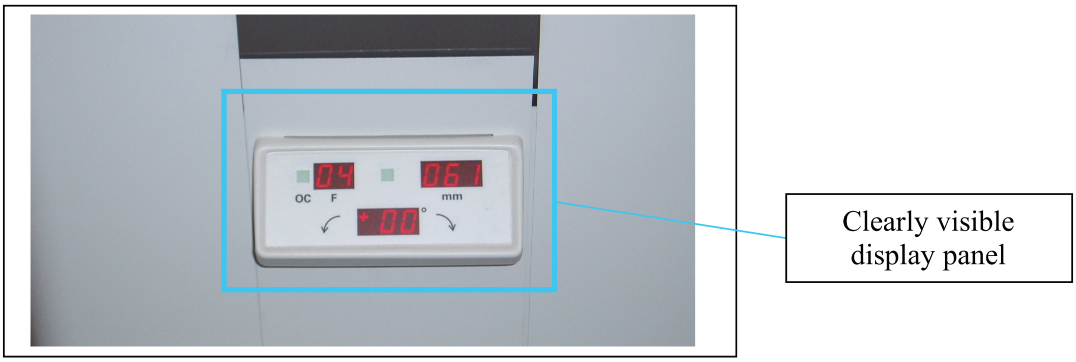


Figure 31 Siemens Mammomat 3000 compression and rotation display.

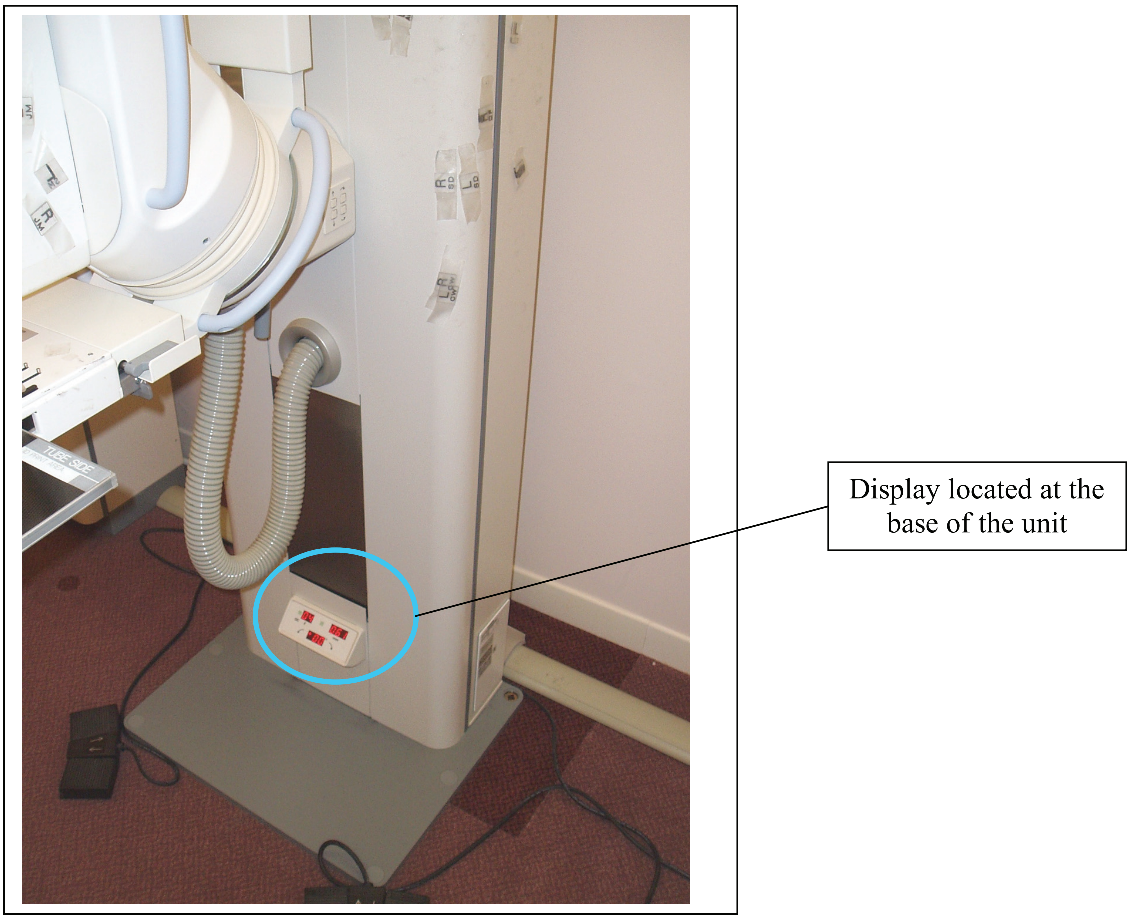


Figure 32 Siemens Mammomat 3000 showing the display located near the floor.

The **GE DMR+** has the display mounted on the support column behind the tube head (Figures 33 and 34). Mammography practitioners have to look away from the bucky to read the compression and rotation information. As this display is directly behind the tube head, it can be obscured when the unit is rotated to the oblique angles. However, the display is set back from the C-arm and is large and thus can be easily located. One criticism of this display is that it does not continually show the compression force information. Moments after compression is halted, the data are cleared from the screen; practitioners must acknowledge the compression force immediately as they are unable to refer back to it. Feedback from the rotation display is not instantaneous, and there is a momentary delay between movement of the C-arm and a readout appearing. This makes it difficult for practitioners to settle the unit instantly at the desired angle and they often have to make slight adjustments to move the unit appropriately. The rotation information is also 'wiped' from the screen upon initiation of compression in order to make way for the compression information (as shown in Figures 33 and 34). The dot-matrix display is also considered cluttered and difficult to read.

Display showing compression information. The display is located on the support column behind the C-arm

Figure 33 GE DMR+ display showing the compression readout.

During rotation, the display shows only rotation angle information. This information disappears once rotation is halted, making way for the compression information that is shown on the same display

Figure 34 GE DMR+ display showing the rotation angle.

The display location on the **Instrumentarium Alpha RT** is poor (Figure 35). It is positioned above the compression paddle under the tube head. When performing the CC views, taller mammography practitioners often have to bend and twist to see the display as it is occluded by the tube head. When performing the MLO views, both tall and short mammography practitioners must bend and twist to see the display as it is angled away from the direct line of sight. In many instances, the practitioner is actually bending below the tube head with her head level with, or even below, the display. The location of the display makes it difficult to see from this position. However, once visible, the display is clear to read and not cluttered.

Figure 35 Instrumentarium Alpha RT showing the display view when at 45°.

On the **Instrumentarium Diamond** the compression and rotation display is located on the control panel (behind the bucky). This is directly next to the area where the mammography practitioner is positioning the breast. It therefore requires no bending and twisting away from the area where the mammography practitioner is positioning in order to obtain any readout information (Figures 36 and 37). The display is also angled upwards very slightly, in such a way that it is easy to visualise from all orientations around the unit.

Figure 36 Instrumentarium Diamond compression and rotation display.

2.1.10 Film marker location

> *The most frequently used film markers should be stored in a position where they can be located rapidly and within easy reach.*

The **Siemens Mammomat 3000**, the **Instrumentarium Alpha RT** and the **Instrumentarium Diamond** all feature 'slide down' markers (Figures 38–40). These are a set of strips that are stored behind the bucky and slide over the face of the bucky when appropriate. They do not detach from the unit.

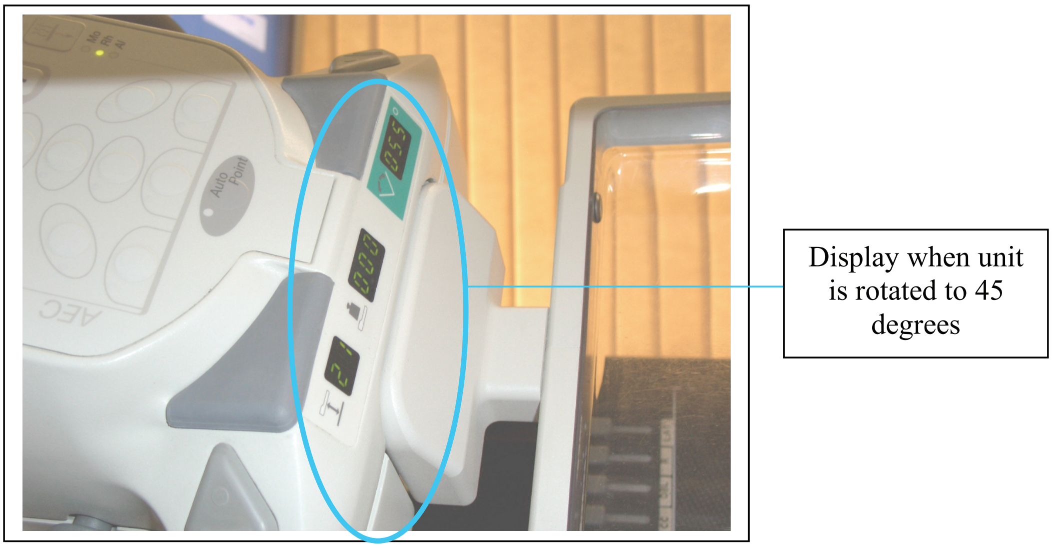


Figure 37 Instrumentarium Diamond display view when at 45º.

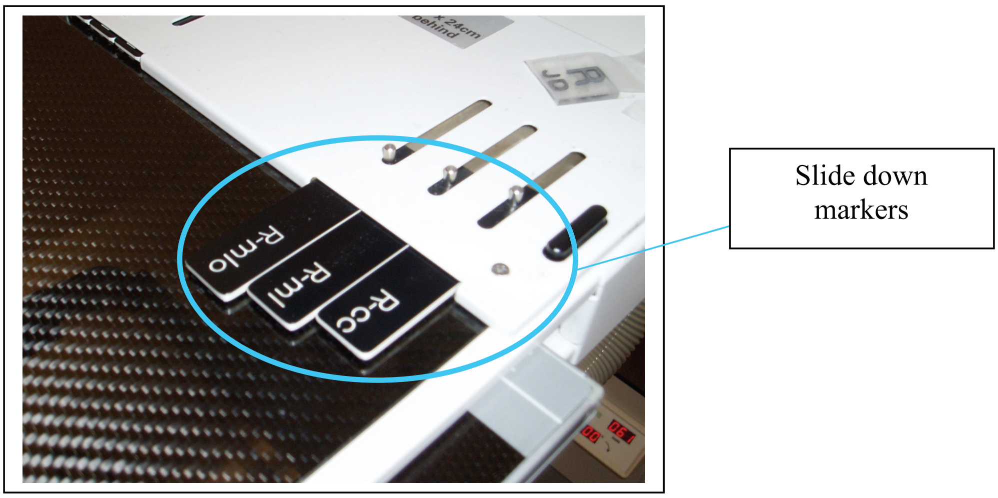


Figure 38 Siemens Mammomat 3000 showing 'slide down' markers.

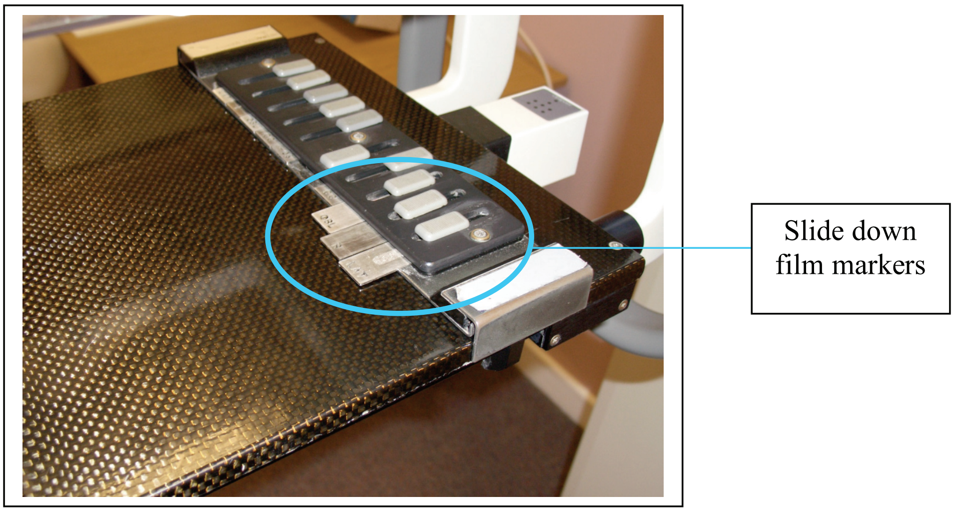


Figure 39 Alpha RT showing 'slide down' film markers.

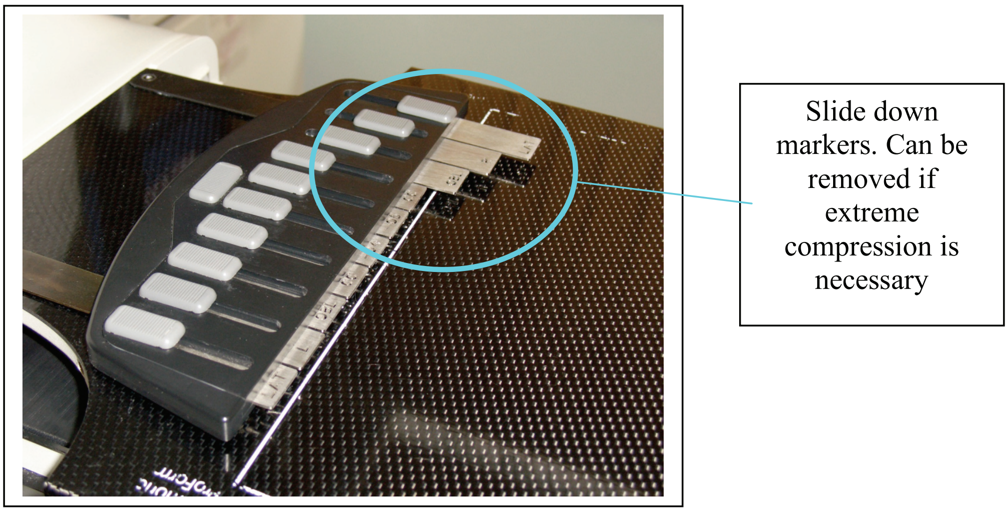


Figure 40 Instrumentarium Diamond showing 'slide down' film markers.

The **GE DMR+** has a cumbersome set of magnetic markers which are fixed to the rear of the bucky and twist down over the bucky (Figure 41). The markers are awkward to move and are frequently pulled off when twisted into position. Some versions of the **GE 800T** and the **Lorad Mark IV** have 'rubber suction' markers. Their holder is not attached to the unit and they are generally stored away from the bucky. These frequently fall off the bucky when it is rotated as the suction is not adequate. Mammography practitioners have been observed to adapt the markers by attaching tape to them to stick to the bucky. As they are not conveniently located near the bucky, practitioners frequently carry their own markers in their pockets as this is more convenient and faster for them to use.

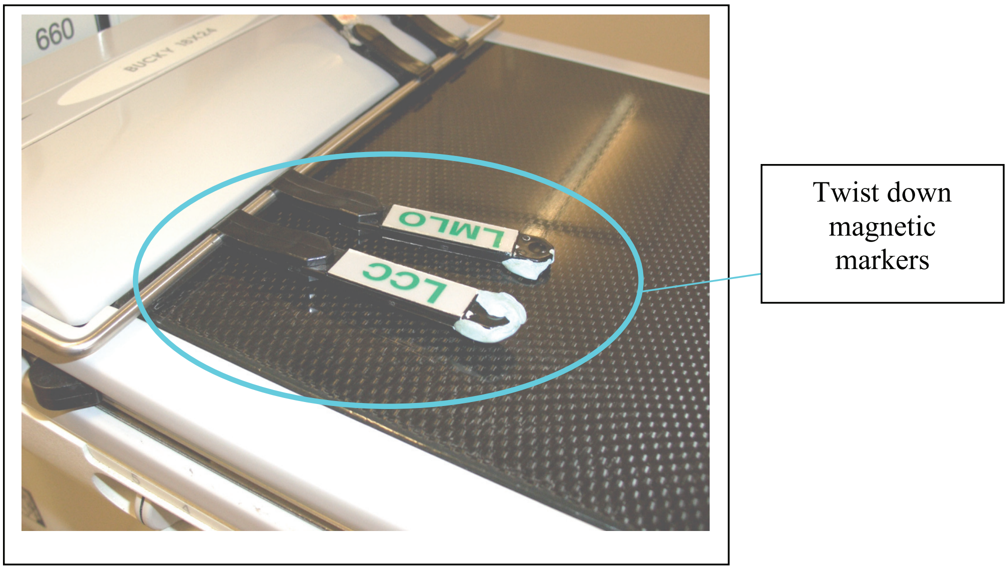


Figure 41 GE DMR+ showing magnetic markers.

2.1.11 Compression paddle

> *The surface of the compression paddle should be coated with a non-reflective surface to reduce the likelihood of glare which interferes with the radiographer's vision when positioning the breast.*
>
> *The range of movement of the compression plate must be from 1 cm from the breast support table to not less than 18 cm from the table. This allows the radiographer better access to the breast.*

Mammography practitioners still complain of glare; however, manufacturing a non-glare surface is difficult as the paddle must be transparent to enable radiographers to perceive the breast. All units exhibited glare from the paddle to some extent.

2.1.12 Weight of the tube head

> *The tube head should be as light as possible and the possibility of providing a motor or power driven C-arm should be investigated. The force used to rotate the C-arm should not exceed 30 N.*

The non-motorised mammography units were the **Instrumentarium Alpha RT**, the **GE DMR+** and the **GE 800T**. The Alpha RT is considered to be light to move and the handles are adequate to provide leverage to move the unit into position. The GE 800T is considered to be cumbersome and heavy to move.

2.2 Additional observations

2.2.1 Isocentric movement

The **Siemens Mammomat 3000** and the **Lorad Mark IV** feature isocentric rotation. When the unit is rotated, the bucky does not rise or drop, but remains at the same height as the previous projection. This feature means that mammography practitioners are not required to readjust the bucky height between projections. In some instances, this will be unavoidable if it is difficult to position the woman; however, isocentric rotation means that any height readjustments are minimal.

2.2.2 Changing the bucky

The **Siemens Mammomat 3000** has a 'fly wing' swivelling bucky feature (Figure 42). Mammography practitioners do not need to physically remove one size of bucky from the unit to fit the other. Instead, they operate a lever and the alternative bucky swivels round from behind the C-arm into position, whereas the bucky that was being used swings back behind the C-arm. All other units require the practitioner to remove one bucky from the unit and attach the other. This can be awkward, requiring force to pull the bucky free from the unit and push the other one into place.

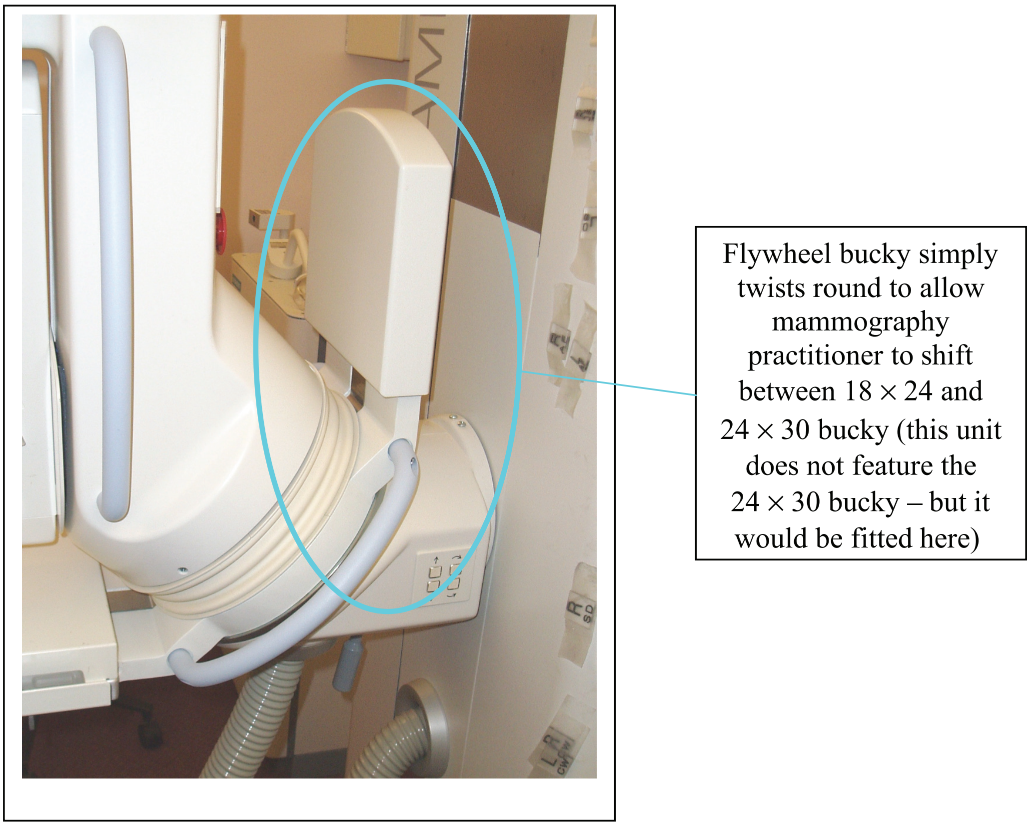
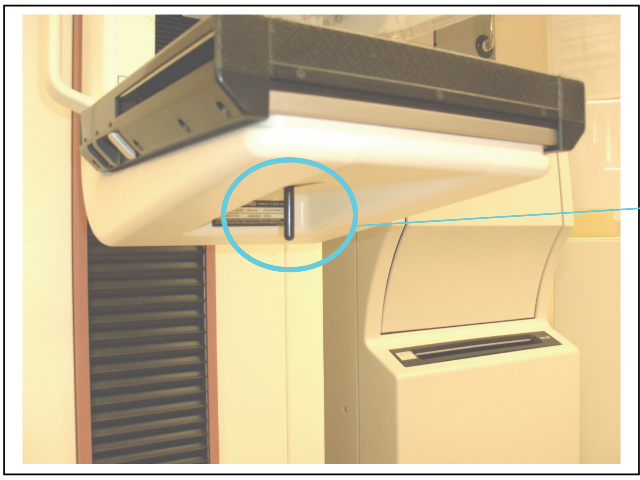


Figure 42 Siemens Mammomat 3000 swivelling bucky.

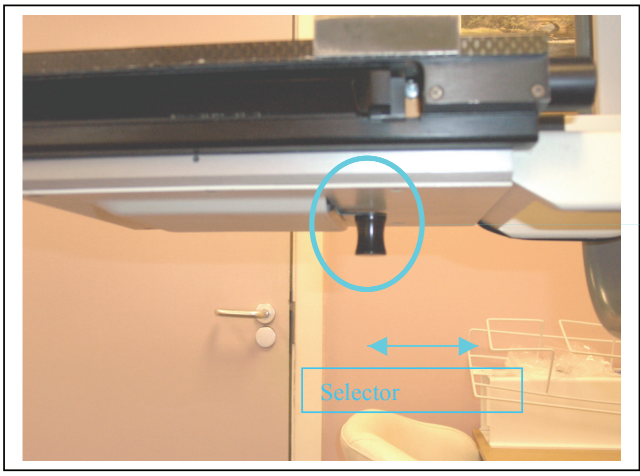
2.2.3 AEC chamber selection

The AEC chamber selection control varies across the units. The **Lorad Mark IV** and the **Instrumentarium Alpha RT** have a rod which protrudes from beneath the bucky (Figures 43 and 44). This is gripped with a fist grip and neutral wrist posture. The fingers and thumbs are not used and the force is spread over this larger muscle group. However, because they are positioned beneath the bucky, the alternative chambers are not easy to see, and mammography practitioners rely on tactile feedback as the selector passes through each chamber making a noticeable 'judder' or 'click'. A beneficial feature of the **Lorad Mark IV** is that the selected chamber is clearly displayed next to the compression display (Figure 45) The **Alpha RT** is described as 'jerky' to move into position; however, it does offer the option of lateral chambers which allow mammography practitioners to take better quality images.



AEC selector handle beneath the bucky

Figure 43 Lorad Mark IV showing the rod type chamber selector.



AEC selector handle. It is positioned under the bucky and operated by pushing away and pulling towards the body

Figure 44 Instrumentarium Alpha RT showing the rod type chamber selector.

The **GE 800T**, **GE DMR+** and the **GE DMR** incorporate a recessed slide selector at the side of the bucky (Figure 46). This is generally operated with the thumbs or a pinch grip. The chambers are clearly marked and there is adequate tactile feedback to indicate that a chamber has been selected. However, relying on the fingers to operate this selector is likely to put further strain on this weaker muscle group as the selector can be stiff to operate.

Figure 45 Lorad Mark IV showing the chamber selection indicator.

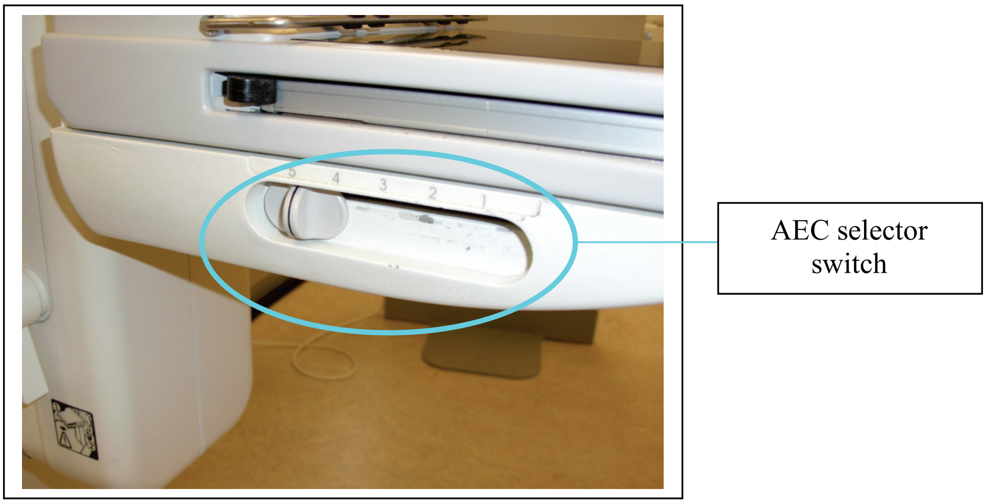


Figure 46 GE DMR+ showing the recessed slide selector.

The **Siemens Mammomat 3000** selector is a lever which is positioned to the side underneath the bucky (Figure 47). It must be slid into place by either the thumb or a pinch grip. The selector is stiff to move and offers little tactile feedback to indicate which chamber has been selected. As a result, mammography practitioners often have to bend to the height of the selector to determine its actual position.

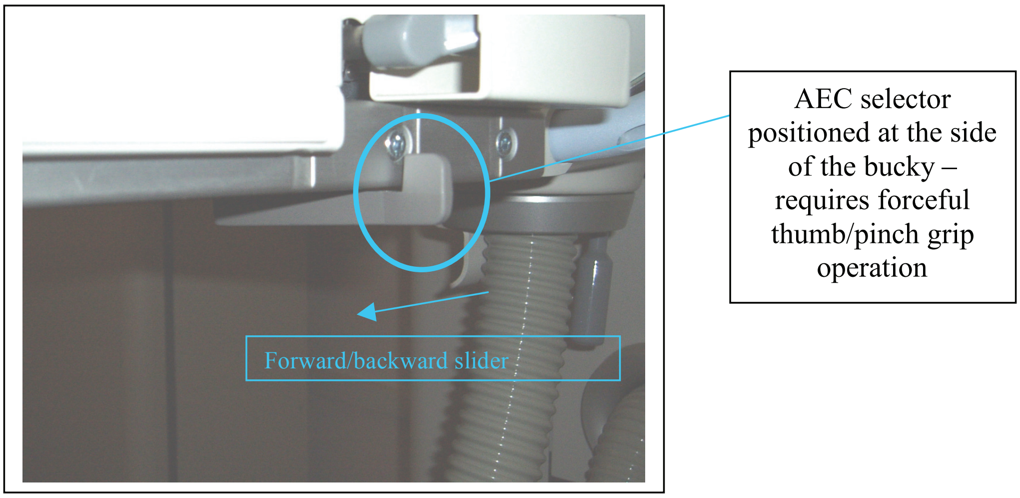


Figure 47 Siemens Mammomat 3000 showing the AEC lever selector.

The **Instrumentarium Diamond** offers automatic exposure control, relieving mammography practitioners of this task. However, in some instances, this must be done manually. The appropriate chamber is selected by choosing one of the options on the control panel, which consists of eight buttons representing different areas of the bucky (the panel is located behind the bucky) (Figure 48). The membrane pad buttons are easy to operate and clear to use.

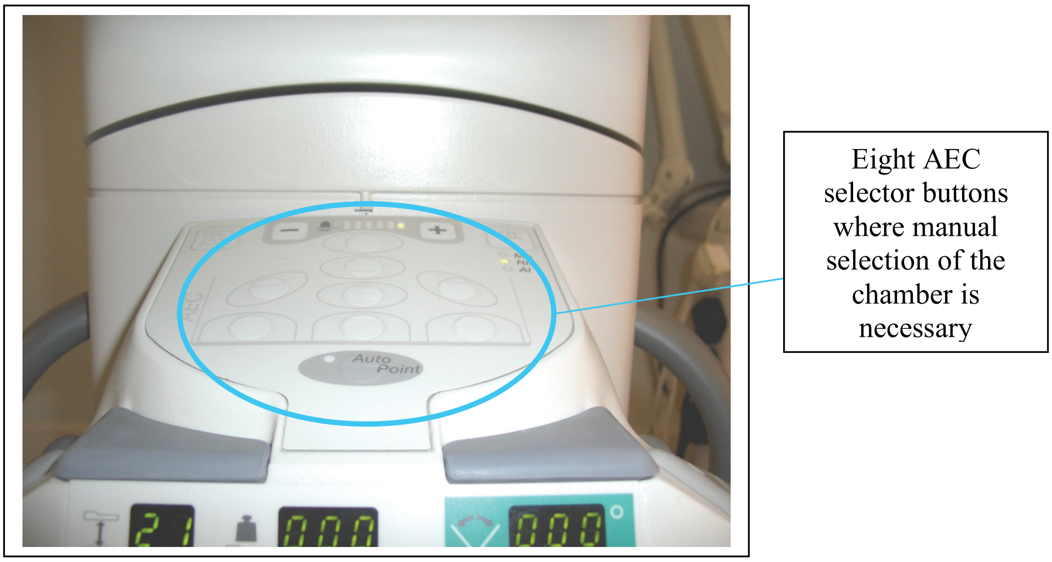


Figure 48 Instrumentarium Diamond showing the chamber selection panel.

2.2.4 Vertical height adjustment

The **GE DMR+** does not drop to a low enough height to accommodate wheelchair users. The **Lorad Mark IV** offers limited legroom beneath the bucky for wheelchair users.

2.2.5 Bucky design

The depth of the bucky has been reported as a problem. It has been reported that units with a deep bucky make it more difficult to position larger women as the bucky has to fit between the breast and the abdomen. Both the **GE 800T** and the **GE DMR+** have been described as having a deeper bucky, which causes problems for mammography practitioners when screening larger women (Figure 49). The **Siemens Mammomat 3000** has a narrow bucky depth in comparison (Figure 50).

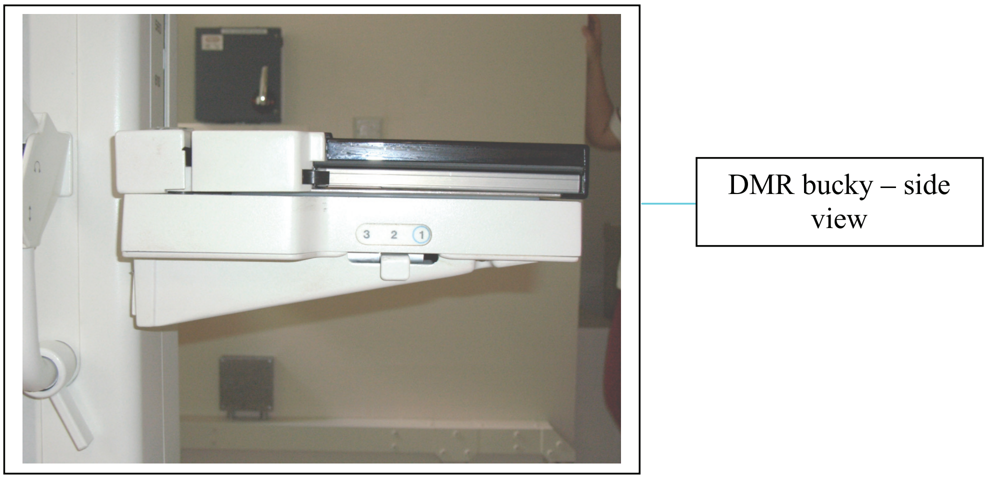


Figure 49 GE DMR+ showing the bucky.

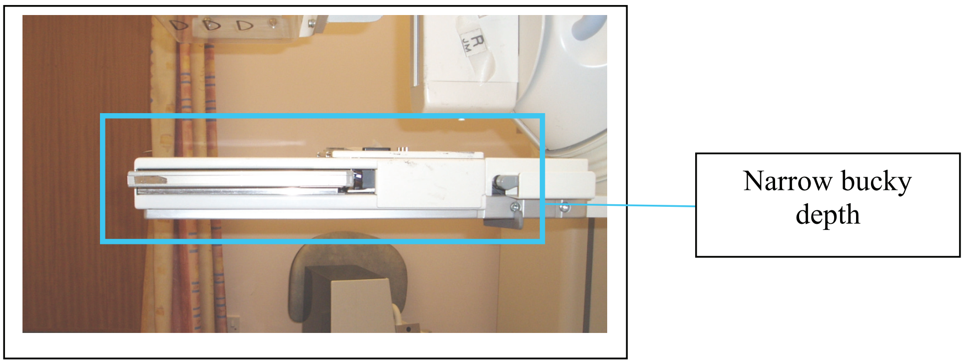


Figure 50 Siemens Mammomat 3000 showing the bucky.

3. ANALYSIS OF THE CURRENT BREAST SCREENING TASK

3.1 Current study

The previous chapter described the assessment of mammography units in current use against the recommendations of the 1997 report. However, there are a range of aspects of breast screening that have changed since 1997, particularly in reference to modern mammography units and their compliance with the recommendations of the 1997 report.

To understand the current situation and to put the 1997 report in its proper, modern context, it is necessary to investigate the wider situation within which mammography units are now operated and to note any key changes which have occurred that are associated with the mammographic tasks themselves. In particular, this study aims to combat work related injury; hence, particular emphasis has been placed on the investigation of the physical demands of conducting mammography and the potential risk for musculoskeletal disorders.

The work was carried out on a small sample of equipment and mammography practitioners, and aimed to update the knowledge contained in the previous report based on current practices rather than to recreate it from first principles. With the expectation that digital mammography will increasingly be used for mammographic screening, and the subsequent importance of understanding the ergonomic implications of this equipment, two digital units were included in the study. It should be noted, however, that owing to their current scarcity within the screening programme it was not possible to observe these digital units within a screening environment.

3.1.1 Data collection

Two mammography centres were visited. In total, eight mammography practitioners performing mammograms were interviewed and observed during their working day. At each centre, observations were also made of the way that x-ray films were mounted onto multiviewers. Table 1 details the units that were observed in operation; these were felt to cover a range of features typically experienced with such units.

Table 1 Units observed

Analogue units	Digital units
Lorad Mark IV (three units)	Fischer Imaging SenoScan (one unit)
Siemens Mammomat 3000 Nova (one unit)	GE Senographe 2000DS (one unit)

3.1.2 Potential limitations to the study

It should be noted that the conclusions of this assessment are based on observation of a small sample of mammography practitioners. Only stressors related directly to conducting mammography were examined, but there may be other broader contributing factors outside the work situation that may also play an important role in terms of psychosocial issues and stress.

For ethical reasons, it was not possible to take photographs or video recordings of the tasks when they were being conducted with women attending for screening. Instead, the photographs used in this report feature mammography practitioners demonstrating the task, with other work colleagues taking the position of the woman being radiographed.

3.2 Background information

3.2.1 Mammography units

Digital units are currently under evaluation for routine use in the NHSBSP; therefore, their use is somewhat limited. Care must be exercised when attempting to compare certain aspects, such as repetitive musculoskeletal effects, with analogue units reviewed in a more hectic screening situation.

Analogue units are used widely as part of the NHSBSP. These units can be permanently located within a centre or situated in a mobile unit that can be transported to different regions. Mobile units present a slightly different situation as they are used in more confined spaces and at a higher rate with shorter cycle times. However, mobile units are not considered in this report. The focus of this study is on units used in permanent locations within screening centres.

Some 4–5 years ago, lottery funding was available to buy new units, and most hospitals trusts bought the analogue units current at this time. These units will be replaced in the next couple of years and replacement units are likely to be digital. It is anticipated that the use of digital systems will increase and become more widely introduced into the NHSBSP.

3.2.2 Work routines of mammographers

Typically in mammography screening centres, each mammography practitioner will see and x-ray 20 clients each day, with five minutes being allotted to each client. After each x-ray session with a client, it takes approximately 4–5 minutes to process and label each client's set of radiograph films.

Symptomatic clinics work at a slower pace than breast screening clinics.

3.2.3 X-ray film cassettes

There are two sizes of x-ray film taken (resulting in two sizes of film cassettes for analogue machines): 18 × 24 cm and 24 × 30 cm. The different sizes relate to the size of breast being imaged:

- 80% of clients have small breasts (use of 18 × 24 cm cassettes)
- 20% of clients have large breasts (use of 24 × 30 cm cassettes)

Some centres use only the smaller size of film cassette (18 × 24 cm). In these centres, when a client has large breasts, two x-ray films from the same view will be exposed to provide two separate partial images of the breast. These are taken with sufficient overlap such that no areas of the breast are omitted. The two x-ray films will then be mounted next to each other to present one complete image of the breast. This results in a client with large breasts potentially having eight x-ray films in one session, which increases workload. Limiting a unit to one size of film cassette also has an impact on the workload for the mammography practitioner taking the mammograms and for the person mounting the films.

3.2.4 Breast weight

Large breasts are heavy and difficult to position. The number of women with large and heavy breasts is increasing, particularly with increasing use of hormone replacement therapy (HRT). HRT can have the effect of maintaining heavier material in the breast later into life. Additionally, the average age of the population (and therefore of screening clients) is also increasing, and older women often have larger breasts.

3.2.5 Reported problems

Mammography practitioners reported that it is difficult to think about the postures that they adopt while working because their priority is the client and getting the job done. Furthermore, it was reported that it is difficult for mammography practitioners to visualise what postures they are adopting. Mammographers commented that, as they are mainly working on their own, they do not often observe other mammographers and certainly never observe themselves. This makes it difficult to see the types of postures that are adopted while conducting the task. Consequently, it was stated by several mammography practitioners that it is very easy to get stuck in a particular routine or method of working, which may work well in carrying out the task but which may not be the most effective in terms of controlling the risk of poor posture.

For instance, one short stature mammography practitioner reported experiencing elbow pain. She stated that it was work related but she was unsure as to the exact cause. Several taller mammography practitioners reported experiencing knee pain, which they attributed to awkward bending to view the breast and reaching foot controls when conducting radiographs, particularly of the mediolateral view.

All mammography practitioners reported that large breasts are heavy and difficult to position and often resulted in thumb and wrist discomfort due to the additional effort required.

Locking and unlocking doors to and from the radiography room was reported as necessitating additional hand and wrist effort because of the twisting action, which was described as being tiring. Also, it may be that doors need to be heavy and secure, but where they are a regular obstacle to the task it is clear that there is scope for improvement.

3.2.6 Overview of the mammography task

Four distinct tasks have been identified as being integral to mammography. These are:

Task 1 – taking the mammograms
Task 2 – processing the x-ray films
Task 3 – mounting the processed films
Task 4 – reading the mammograms.

This report focuses on the first three tasks, as task 4 is outside the remit of the work. Tables 2–5 present an overview of the tasks and the subtasks that occur within each of these processes, for each type of unit (analogue and digital).

Table 2 Task elements of taking mammograms

Task element		Analogue	Digital
Collect notes and film cassettes		✓	✗
Show client into the x-ray room		✓	✓
Check client's details; complete form/data entry via computer		✓	✓
Client undresses		✓	✓
Take mammograms		✓	✓
Craniocaudal view (right breast) Craniocaudal view (left breast) Mediolateral view (left breast) Mediolateral view (right breast)	Assess whether support table is correct size	✓	✗
	Label support table	✓	✗
	Adjust breast support table position	✓	✓
	Place breast on support table	✓	✓
	Position breast and apply compression	✓	✓
	Take mammogram (activate radiation)	✓	✓
	Release compression	✓	✓
	Check image of sufficient quality and full image, no artefacts	✗	✓
	Remove cassette	✓	✗
	Name cassette	✓	✗
	Check all digitised images and send	✗	✓
Client gets dressed		✓	✓
Return client to waiting room		✓	✓
Clean unit		✓	✓
Carry completed cassettes out for processing		✓	✗

Table 3 Task elements of processing x-ray films

Task element		Analogue	Digital
Process x-ray film	Load completed film cassette into processor	✓	✗
	Retrieve empty film cassette from processor	✓	✗
	Place empty cassette onto empty cassette pile	✓	✗
Retrieve processed films from the processor		✓	✗
Mount films on viewer and check for full image, artefacts, etc.		✓	✗
Stick appropriate identity label onto each film		✓	✗
File films		✓	✗

Table 4 Task elements of mounting processed films onto a multiviewer

Task element		Analogue	Digital
Sort out files for a client		✓	✗
	Retrieve the current file of x-ray films	✓	✗
	Retrieve previous file	✓	✗
Mount each film onto the multiviewer		✓	✗
Place the empty file in the appropriate empty file box		✓	✗

3.3 Postural assessment

The operations conducted by the mammography practitioner on analogue and digital units were examined in relation to the key risks of work related limb disorders: force, posture, repetition and duration. The assessment of mammography practitioners conducting mammography was based on:

- observations of each mammography practitioner adopting typical working postures on analogue units and digital units
- frequency and duration of task cycle times.

The assessment procedure was conducted based on static and limited dynamic observation made during each visit. It therefore provides only an indication of the type of problems caused by poor and awkward postures that are likely to increase the risk of musculoskeletal disorders.

For the purposes of postural assessment of the tasks involved, a detailed breakdown of the mammography task into its subtask elements was first conducted. Physical actions required in each task element were then assessed. This highly detailed part of the work was carried out primarily for analogue mammography because this also covers the main posture related tasks involved in digital mammography. Digital mammography involves fewer task elements, and its associated procedures are not as well established nationally as they are for analogue mammography. Any postural implications found to be specific to digital mammography or the digital units investigated are detailed separately later.

The tables in Appendix 1 present in detail a full breakdown of the tasks associated with using mammographic units into their subelements and the physical actions required. The next section of this report discusses specific elements of the mammography task that were identified as presenting medium to high levels of risk for musculoskeletal injury.

The task analysis charts in Appendix 2 may be used as a ‘map’ for placing the detailed task elements given in Appendix 1 within the wider mammographic process. The charts in Appendix 2 cover a wider breadth than the detailed tables in Appendix 1, including for comparison task analysis for analogue (charts 1 and 2), digital (charts 3 and 4) and ‘fully’ digital (chart 5) mammography. Additionally, these go beyond the tasks involved with the mammography unit and subsequent film processing to include tasks associated with mounting the processed films and/or images in preparation for screening. Appendix 2 and its task analyses are discussed in more detail in section 3.4.

3.3.1 Task elements of medium and high risk

The adoption of awkward postures, particularly at extreme ranges of motion, increases the risk of musculoskeletal disorders. Awkward postures include any fixed or constrained position or any postures which overload muscles or tendons, load joints in an uneven or asymmetrical manner or involve static loading. Assuming and sustaining awkward postures can induce significant biomechanical stress on the musculoskeletal system. Prolonged postures or repetitive motions should be kept close to the body segment's neutral position and preferably should be broken up with significant rest breaks or alternative positioning.

The tasks of positioning the breast, applying compression when taking the mediolateral view, manipulating and orientating film cassettes and mounting radiographs onto the multiviewer through a combination of applied force and poor or awkward posture in association with the frequency with which these postures are adopted result in medium to high risk. Sections 3.3.2 to 3.3.5 discuss each of these task elements in detail. Furthermore, aspects in which significant differences were observed between postures adopted in the use of digital and analogue units are also discussed.

3.3.2 Positioning the breast

- Level of risk: medium/high (particularly when taking the mediolateral view)
- High risk to: elbows, wrists and thumbs

Task description
The mammography practitioner needs to view the breast to position it correctly on the support table and to ensure that the nipple is appropriately positioned and that there are no artefacts or skin folds. The practitioner applies force to hold the breast. This application of force is sustained until the breast is correctly positioned and slight compression is applied. This task can be repeated in succession four times in a single five minute session (this can increase to eight times depending on the size of breast and the availability of different sized cassettes; see section 3.2.3). This equates to conducting this task element approximately 80–160 times per day.

Physical actions
To maintain a view of the breast, it is necessary for the mammography practitioner to frequently twist and extend her neck and also to bend at the trunk. Both of the mammography practitioner's legs are bent and positioned apart to lower her overall body position and to enable her to view the breast, which otherwise would be obscured by the head of the machine. This posture is more pronounced when taking images of the mediolateral view, and is even more pronounced for digital units than for analogue units (Figures 51 and 52).

For both the craniocaudal and mediolateral views (on both types of unit), the mammography practitioner often achieves the correct position of the breast through excessive extension of her arm at its maximum range of motion across the support table (see Figures 51 and 52). For the craniocaudal view, the mammography practitioner lifts up the breast in the palm of her hand in order to form a right angle with the woman's body. This requires supination of the mammography practitioner's forearm combined with radial deviation and extension of the wrist and also forces the thumb into hyperextension. For the mediolateral view, there are two different positioning techniques used.

- *Technique 1* The right hand thumb is fully extended and is used to support the weight of breast and to push the breast up to the correct position on the support table. Use of the thumb allows the forearm and wrist to stay in line. However, the thumb is used in a weak position (fully extended) to take the full weight of the breast. The use of the thumb in this posture with such a load places the thumb and wrist at risk of injury, particularly with the rate of repetition and duration that this posture is adopted.

Figure 51 Taking the mediolateral view using an analogue unit.

Figure 52 Taking the mediolateral view using a digital unit.

- *Technique 2* The fingers are used to support and push the breast into position. This requires the elbow to be held outwards to rotate the forearm so that the palm of the hand is able to push up against the breast. This will lead to awkward rotation of the shoulder and elbow joints. The other hand (not holding the breast in position) is used to keep the shoulder, stomach and other breast from protruding into the field of view for imaging.

Risks

Viewing the breast Neck stress is often experienced with hand–eye coordinated tasks. The mammography practitioner's view of the breast may be obscured by features of the mammography unit, and this may result in awkward extension and twisting of the mammography practitioner's neck. In addition, maintaining a clear view of the breast causes the mammography practitioner to adopt an overall awkward posture, which is sustained throughout the task. When adopted frequently, there is risk to the neck, back and knees.

Supporting and positioning the breast The two techniques for holding the breast in position present risk either to the thumb and wrist or to the elbow. There is a risk of injury when the wrist is rotated into pronation or supination combined with ulnar or radial deviation while extended. This risk is significantly increased when combined with the application of force, eg supporting the weight of the breast. The larger and heavier the breast, the greater the risk. This risk is significantly greater when conducting the mediolateral view, as the application of force is sustained for a much longer duration. The mediolateral view requires the support table to be at an angle, which can cause the breast to slip and fall out of position; therefore, the mammography practitioner has to push and hold the breast in position for a longer duration, until some compression is applied.

In addition, positioning the breast requires the mammography practitioner to work with her arms above or just below shoulder height and with her arms outstretched. A simple reach triggers a complex action of the arm and hand. Muscles that originate in the forearm control the wrist and finger motions. Therefore, awkward wrist positions and forearm motions can cause pain at the elbow.

Summary

This task action occurs interspersed with other significantly different tasks (in which the mammography practitioner uses other body parts in a significantly different way and with less force). Therefore, in the analogue process at the current rate of working, and with the built in less intense tasks such as film processing, the risk associated with this task element is currently rated as medium. However, if this task element were sustained for a prolonged period of time and/or repeated at a higher rate, it would result in high risk.

3.3.3 Applying compression: mediolateral view

- Level of risk: medium/high
- High risk to: neck, back and knees

Task description

The mammography practitioner uses her left or right foot to depress a foot pedal to activate compression. This is conducted while supporting and smoothing the breast to maintain its correct position on the support table. Once some compression has been applied (sufficient to hold the breast in place), the practitioner removes her hand and applies full compression. This requires the practitioner to maintain a view of the breast and to read the compression level display. The overall posture is sustained until the breast is correctly positioned and full compression is applied. This task can be repeated in succession 2–4 times (depending on the size of breast and the availability of different sized cassettes; see section 3.2.3) in a single five minute session.

Physical actions

Combined use of the foot pedal while keeping one hand on the breast (to maintain its correct position) often results in an asymmetrical posture for the mammography practitioner. When a mammography practitioner uses the foot pedal, it destabilises her posture; therefore, additional effort is required from the trunk and opposite leg to maintain an upright stance. In addition, the supporting leg remains bent with the trunk slightly stooped and the neck is kept extended and twisted to maintain a view of the breast and the compression display during the application of final compression. This further increases the unequal distribution of weight placed on the supporting leg and twisted trunk.

Some mammography practitioners are starting to conduct this part of the task while seated. Once the breast has been positioned and some slight compression has been applied, the practitioner will pull the chair behind her to sit. She then proceeds to apply full compression. From limited observation, this appeared to reduce the degree of neck extension and to reduce the demands placed on the supporting leg. In addition, a slightly better, more upright, trunk posture could be maintained while applying full compression (Figures 53 and 54).

Figure 53 Taking the mediolateral view using an analogue unit while seated.

Figure 54 Mammography practitioners taking the mediolateral view using a digital unit while seated.

However, issues of locating the seat and being able to sit down on it without it scooting off require consideration. The mammography practitioner typically sits down on the seat without turning round to check its exact location. Furthermore, practitioners were limited to one hand to hold the chair while they lowered themselves into it. The design of the seat used needs careful consideration because it is important that it provides good stability. It was observed that practitioners typically perch on the edge of the seat; this may increase the likelihood of the seat moving out from under them. The presence of arm rests on the seat provides an important tactile cue to its position.

A saddle seat was present in one centre; however, this was of incorrect size for the majority of the mammography practitioners (it was too big) and it was also difficult to mount and dismount and was reported as causing more problems than it solved.

Summary

This task action occurs interspersed with other significantly different tasks (in which the mammography practitioner uses other body parts in more neutral positions and in a significantly different way). Therefore, in the analogue process with the current format of working, the risk associated with this task element is rated as medium. However, if the actions of this task element were sustained for a prolonged period of time and/or repeated at a higher rate it would result in the task being high risk.

3.3.4 Inserting, removing and manipulating film cassettes

- Level of risk: medium
- Medium risk to: wrists and thumbs

Task description

The mammography practitioner picks up a new cassette and flips it so that the correct surface is facing upwards (labels facing downwards). Next, the mammography practitioner moves the switch to the side using either her thumb or the palm of her hand (Figure 55). The mammography practitioner then inserts the cassette into the slot. Once the exposure has been made, the practitioner removes the cassette from the support table by moving the switch with her thumb or palm and then reaching with her other arm round to push the cassette up and out from the bottom. The practitioner then flips the cassette over so that the labels face upwards (Figure 56) and places the cassette into the naming machine. This cycle is repeated after each view of the breast. This action is conducted 12 times in each five minute session.

Physical actions

The mammography practitioner twists her wrist from supine to prone, and applies force with her thumb to move the switch when inputting or removing each cassette. This places some localised pressure and stress on the thumb.

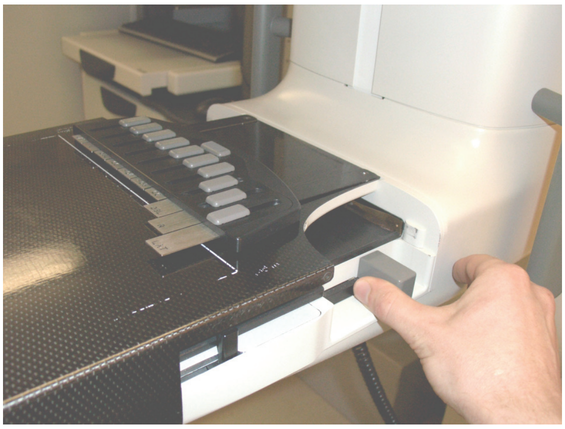


Figure 55 Switch to insert and remove film cassettes.

Figure 56 Mammography practitioner removing film cassette from the breast support table.

3.3.5 Mounting processed films on to the multiviewer

- Level of risk: medium/high
- Medium risk to: shoulders and wrists

Task description

Each morning for approximately one hour, staff mount the previous day's mammograms for each client onto multiviewers for readers to view and assess (Figure 57). This requires picking up files, separating each x-ray film and pushing these onto the light box of the multiviewer. The mulitviewer is positioned vertically in front of the mammography practitioner. If a client has been screened previously, her films from three years ago will also be mounted along with the new films for comparisons to be made. Therefore, each practitioner will mount approximately 80 sets of films. Typically, each set will comprise four films. In the course of one hour, an individual practitioner will mount approximately 320 films. This equates to one film mounted every 11.25 seconds. This task is conducted only for mammograms produced from an analogue machine.

Physical action

The mammography practitioner must perform fine dexterous hand and finger movements with the wrists often in extension.

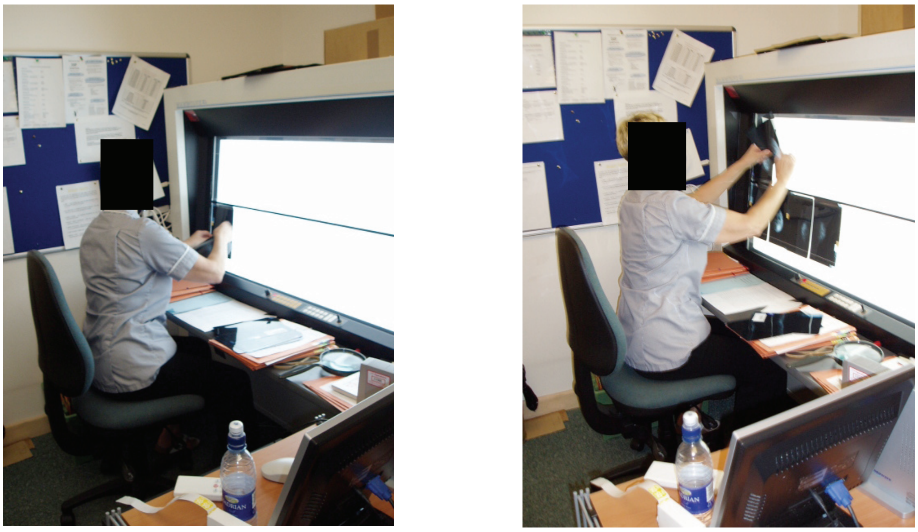


Figure 57 X-ray films being mounted onto a multiviewer.

Risk
The main risks associated with this task are the high rate of repetition and working with the arms held out unsupported for a prolonged period of time. As this task is conducted for an hour in the morning, the degree of risk depends on the other tasks that a practitioner performs after this task and whether they are similarly hand intensive. It was also noted that the workstations offered restricted leg room, which further constrained the practitioner's posture.

3.4 Task analysis

A task analysis was constructed for conducting the mammography task. This included: taking the mammograms, processing the images and mounting the processed films. The task analyses are shown in Appendix 2. Task analysis charts 1 and 2 present the task procedures when an analogue unit is used. Task analysis charts 3 and 4 present the task procedure for a digital unit after immediate introduction, and task analysis chart 5 presents the task procedure of processing film and mounting film when all previous cases are also digital images. On task analysis charts 3, 4 and 5, the task modules shaded in grey are previous tasks required in the use of analogue machines but which have been eliminated in the digital process, and task modules shaded in yellow are new tasks that occur only in the digital process.

Overall, the operation of a digital unit reduces the number of task elements conducted as part of the mammography task compared with an analogue unit (see Tables 2–5). In summary, the digital process eliminates the following task elements:

- carrying and orientating film cassettes
- loading and unloading cassettes into the support table
- loading and unloading cassettes into the naming machine
- the need to change the support table and compression paddle
- the need to adjust the position of the exposure chamber
- film processing – loading and unloading cassettes into the processor
- the need to recall a client following an incomplete or blurred image
- the mounting of processed films.

The removal of these tasks will reduce the physical effort required per client, and could potentially reduce the overall risk presented by the whole task.

The digital units introduce a few new task components. These include:

- inputting client details into the computer system
- checking that each image is of sufficient quality after each image exposure
- checking (on screen) that all four complete images are taken and then sent or stored.

These new tasks are not physically demanding and present no additional risk.

However, the tasks of positioning the breast and taking radiographs in craniocaudal and mediolateral views remain primarily the same in the digital as in the analogue process, and it is these tasks which are classed as presenting the highest risk of musculoskeletal disorder. Furthermore, in some instances, it was apparent that the use of digital units resulted in more excessive reaching and twisting than the analogue machines when conducting the mediolateral view. It is suggested that this is due to the lower height and larger size of the head of the unit arm, which acted as a larger obstacle to mammography practitioners when viewing the breast.

Although the use of digital units would reduce the overall risk of musculoskeletal disorder, there is a concern that if digital systems are not properly introduced, problems may increase rather than be reduced. The removal of task elements required for analogue mammography will result in a shorter time to see and x-ray a client. This will increase the rate of repetition at which the higher risk task elements such as positioning the breast and conducting the mediolateral view are conducted. It will also mean that the body is given fewer rest breaks from adopting awkward postures and between repeating the same actions. Currently, the task element of processing x-ray films provides a built in break, during which awkward postures are not adopted. With the removal of these low physically demanding tasks which encourage neutral postures, thought needs to be given to how naturally occurring micropauses can be built into and become part of the digital task.

4. SUMMARY AND CONCLUSIONS

4.1 Assessment and comparison of current units with 1997 report

It is clear that the situation in mammographic screening has changed since the 1997 report. In particular, very few of the units investigated previously are currently now in use; more modern units have been introduced in their place. It is evident also that, in general, manufacturers have begun to respond by introducing more ergonomically designed aspects of their units, and this appears to have resulted in a reduction in serious work related stresses and injuries. However, it is also evident that there is still scope for improvement across a number of aspects, particularly (but not exclusively) those related to the use of the wrist and thumb.

As was indicated earlier, there are four broad features of a physical task which place strain on the musculo-skeletal system. These are:

- excessive bending and twisting
- static working postures
- forceful movements
- repetitive working cycles.

The 1997 report highlighted many aspects of the screening process that involved the performance of harmful tasks by mammography practitioners. The eventual aim of equipment design is to limit the frequency with which these occur. Since 1997, some basic changes have occurred to many mammography units that have reduced the frequency with which harmful tasks are carried out, eg motorised units, lightweight units with isocentric rotation and the provision of more accessible controls. All of these developments serve to make the mammography task less physically demanding.

Many units (Siemens Mammomat 3000 Nova, Lorad Mark IV, Instrumentarium Diamond, Instrumentarium Performa, Philips MammoDiagnost) are now motorised, meaning that the C-arm is power driven. This reduces the amount of force required when positioning the unit. Other units which are not motorised are lightweight or are isocentrically weighted for easy rotation, although the GE 800T is still considered to be relatively cumbersome by its users. However, fully motorised movement is the desirable endpoint, and should be accompanied by suitably placed controls that do not require uncomfortable postures in order to be operated effectively. The need to assume a largely static posture through holding motor controls while movement is carried out should also be avoided where practicable, particularly in situations where the necessary posture is tiring. The Instrumentarium Diamond, for example, uses pre-set memory positions that allows automatic positioning in some situations.

All of the units reviewed showed improvements to the location of primary controls. This is important in accommodating users of different stature, who work in different orientations, by allowing them to introduce variation into the way in which they control the units (thereby reducing repetition of identical actions). The Lorad Mark IV was possibly slightly less successful than the other units in this respect, however, with the high position and/or inconvenient location of its rotation controls. Additionally, there were some reports of accidental operation of this unit's controls, whereas other models had recessed controls which seem to prevent this.

The light beam switch position varied across the units. The GE DMR+ was found to be in a less favourable position than the other units that were reviewed but, otherwise, the units generally positioned these well, with the Instrumentarium Diamond being particularly good in this respect. In most cases, the light beam was also linked automatically to the compression controls, which was particularly convenient for the operator.

Exposure buttons are generally finger operated, some units having two buttons and some having a separate control that could be hand held or positioned flexibly. The units that allowed flexibility in the method of exposure operation were favoured. It was felt that the more substantial controls would be better suited to being operated by the palm (rather than a digit), and would reduce fatigue in the fingers and thumbs. Usually, operators are female with relatively small fingers and thumbs; hence, this is a factor worthy of consideration. In particular, the Instrumentarium Diamond had a single button that appeared to encourage operators to extend their thumb and wrist quite notably when operating it.

Final compression was found to be power driven in all units, and is controlled by foot pedals. This is according to recommendations given in the 1997 report; however, it appears that in some cases the motion is not sufficiently smooth or responsive to allow easy fine-positioning, which can increase the time and physical demands needed on the task. The Instrumentarium Diamond and Alpha RT both have systems which provide useful help with the task by moving the bucky upwards slightly as the compression lowers. Additionally, most units automatically removed compression after exposure, meaning that the practitioner was not required to carry out this task. There was concern that the paddle depth was too shallow on the GE 800T, causing difficulty with the compression task and greater discomfort for some clients.

Foot pedals were found to vary substantially across the units reviewed. Some required more ankle deviation than others to accommodate the foot, which put more strain on the lower leg. Some foot pedals were easier to move about and reposition than others, although sometimes at the cost of the functions they provided. Functions that duplicated the actions of switches and buttons were felt to offer more opportunity for varying posture and methods of operation, although with complicated pedals users sometimes found it difficult to locate the correct pedal without bending to look at it. Therefore, foot pedals need to allow easy repositioning and pedal selection in a low height design, ideally with foot support, that also offers a number of other functions. Some units managed better results than others.

Handles were not necessary with motorised units, and were provided on all manual units. These were generally good, although the position of the second handle could have been better on the Instrumentarium Alpha RT.

The insertion and removal of the film cassette was an area where little improvement was evident since the 1997 report. This was noted as causing particular strain on thumbs and wrists, which coincides with one of the more reported areas for work related injury in mammographic screening. The Lorad Mark IV and the Siemens Mammomat 3000 had made some attempt to address cassette removal, although this did not extend to the release mechanism. The Instrumentarium Diamond had addressed one aspect of film loading by mechanically drawing the cassette in; however, a more complete solution that addresses all ergonomic aspects of cassette loading, locking, release and unloading would have been preferable.

Displays for rotation and compression information were quite varied in both their design and their location; they also varied in their degree of ergonomic success. Some displays were positioned a little too high for shorter operators, whereas others were in positions where they were obscured in certain configurations of the unit. Generally speaking, it appears that displays positioned lower down but so as not to be obscured by the C-arm or to require only limited deviation of the neck to view them were more successful. It was suggested that, as with the controls, repeating the display in more than one location could offer better results. The clarity of the information within the displays also varied, and this was not restricted to size and visibility. In the case of the GE DMR+, for example, temporal delays in readout response made quick, accurate positioning difficult, and compression data did not remain on the screen after compression had halted, making subsequent checking and referral difficult. On the same machine, rotation information was not shown concurrently with compression data, again making checking difficult. These seem to be relatively simple disparities between what the display provides and what the user needs from it in typical use.

Different types of film marker were used on the units. Some used slide down non-detachable markers that appeared to work relatively well. The magnetic markers on the GE DMR+ were found to be more cumbersome and could be pulled off by accident. Rubber suction markers on some other units suffered from similar problems because of failing or inadequate suction. Some detachable markers were also said to be inconveniently located, encouraging users to carry them in pockets rather than keeping them in the intended location. Such unofficial adaptations are unpredictable in their effect and are believed to be unnecessary.

Glare on compression paddles was still found to be an issue with users, and all units exhibited it to some degree. It is appreciated that the creation of a transparent matt paddle may be challenging to manufacturers, yet it would be an improvement if they were able to provide such a solution.

It is difficult for manufacturers to change the placement of the tube head. However, the 'park back' head feature on the Instrumentarium Diamond may be the first step to giving users greater room for manoeuvre.

In some cases, changing the bucky can be an awkward operation. The Siemens Mammomat 3000 has an innovation that involves the bucky swivelling to offer one of two sizes as required, rather than exchanging them manually.

There was some variation in the ease with which the chamber can be selected. Including a chamber readout on the display was noted as being a particularly useful feature compared with using touch and/or lever position. Slide selection commonly involves the use, sometimes under force, of the fingers and thumbs. Given that this is currently an area of the body where injury is occurring, it should, ideally, be improved.

There were variations in the thickness of the bucky. The Siemens Mammomat 3000 had a slim design; however, the GE 800T and GE DMR+ had much thicker buckys. These thicker designs were said to cause difficulties in positioning larger women.

The GE DMR+ and the Lorad Mark IV were noted as having insufficient height adjustment and limited underside clearance, respectively, to accommodate wheelchair users. The population of screening clients includes wheelchair users, and hence this is a problem that should be addressed.

4.2 Analysis of the current breast screening task

4.2.1 Posture

The use of digital units eliminates eight subtask elements that occur in the analogue process. However, it does not eliminate all high risk tasks. Efforts to reduce the risks of the remaining high risk tasks of positioning the breast and applying compression are therefore required. This may include looking at the design of the C-arm and face shield to reduce the visual obstacle they currently pose to mammography practitioners and providing some device which will remove the requirement for the mammography practitioners to lift and support the breast. In addition, the introduction of effective micropause and rest breaks is very important.

4.2.2 Cycle time

As it was possible to observe the use of digital units only in symptomatic clinics, it is unclear what the exact reduction in cycle times would be when digital units are used in the breast screening programme. However, the use of digital units will significantly reduce the time taken to conduct a session. This may increase the risk of injury because other high risk tasks are still present. A reduction in cycle time will mean that these higher risk tasks are conducted more frequently and at higher rates of repetition, thereby significantly increasing the risk of injury that they currently present in the analogue process. Although the overall time spent screening each woman may not be shortened through the introduction of digital image acquisition (most breast screening units allow six minute appointments for two view screening), the various individual tasks may be performed faster than with an analogue set up.

4.2.3 Need for micropauses

The absence of the film processing task (conducted in the analogue process) removes a large time span in which a natural rest break usually occurs. Although some time is spent viewing the digital image on the VDU screen, this is very short compared with the break previously provided by the film processing. An alternative work flow incorporating an opportunity for rest in the digital process should be considered and investigated. Mammography practitioners would benefit from actively taking micropauses, which could be built into the overall task. Micropauses range from a few seconds to a minute, and should enable rest and the adoption of alternative postures to provide recovery and rest to structures.

4.2.4 Use of seating

The use of a seat during mammography needs further investigation, and the design of the seat used requires careful consideration. It is important that, if a seat is to be used, it provides good stability. It was observed that mammography practitioners typically perch on the edge of the seat; this may increase the likelihood of the seat moving out from under them. In addition, the seat would need some form of arm rests so that it could be easily located and positioned correctly.

4.2.5 Interim period between film and digital images

As digital systems become more widely introduced into the breast screening programme, there will be a period of time during which the current screening process will use digital imaging and any prior screening of the women concerned will have used analogue film. This means that reporting cases will, for some time, involve the comparison of digital with analogue cases. Given that the two image types appear visually different and require different viewing equipment (ie multiviewer versus VDU screen), comparisons between images may be problematic and could lead to errors of omission. Comfort of the reader may also be compromised.

There are three options for comparing analogue and digital cases:

1 Previous analogue cases could be digitised to enable direct comparison using like for like media. However, problems may arise as this will rely on the quality of the image acquisition system and digitiser used. This process would result in the removal of the mounting task but could place different physical demands on the readers as they may need to maintain a fairly static position and view a VDU screen for prolonged periods of time. Correct VDU workstation design is therefore very important. Additionally, the digitisation of prior films is a new task which would need to be introduced if this option is followed.
2 Digital images can be printed off onto film and mounted side by side with the previous films. However, this is reliant on the quality of the printing of the digital images. This would not alter the current task other than to introduce the need for the mammography practitioner to print out each digital image after each client's examination.
3 The previous films could remain analogue and the current digital images could be mounted in close proximity to the digital images on the VDU. This would require an appropriate ergonomic layout of the multiviewer and the digital workstation. In one centre, this method of comparison was being used. However, the workstation layout was poor and resulted in excessive and frequent twisting of the neck to view the multiviewer and the VDU screen, which were set up at a right angle to one another.

4.3 Potential future work

There is much potential for further work, both through resolving the current problems detailed above and through the introduction of new aspects to the screening process, such as digital mammography.

Digital mammography would be expected to bring its own design related innovations and challenges as well as to change the breast screening process itself in potentially important ways. This report has attempted to gauge its effect where possible, but being a relatively new and important development it has not yet been possible to gain a fully rounded picture of the ergonomic implications of digital mammography in breast screening. It is expected that further work would be appropriate in this area when digital units are being used by the breast screening programme on a greater scale nationally.

There are additional specific issues that would warrant further work; these include:

- investigating whether a mechanism can be developed to aid or eliminate the need for mammography practitioners to apply force with the thumb or palm to support the breast while the support table is angled when taking the mediolateral view
- reviewing mammography units in the light of the specific design recommendations mentioned above, with particular emphasis on those related to posture and to the hand/wrist/thumbs; this may involve (patents permitting) combining the best design principles from each unit in each section detailed. There is still room for design improvements on each mammography unit observed
- considering the effect of conducting the task while seated and the requirements for an appropriate seat design, taking into account the features noted on digital units
- investigating how to build micropauses and significant rest breaks into the digital process and what form these should take
- providing an appropriate workstation design for comparing film with digital images; this is currently under way
- conducting research into the effectiveness of comparing images presented on two different media (film and digital); this is also currently under way.

APPENDIX 1: DETAILED TASK ELEMENTS FOR POSTURAL ANALYSIS

Table 5 Task elements and actions involved with an analogue mammography unit

TA task number	Task element	Control/equipment action	Physical action
1.0	**X-ray**		
1.1	Bring in four new cassettes	Place cassettes on the side	
1.2.1	Open the door and ask the client to come into the room		
1.2.2	Confirm the client's details		
1.2.3	Lock the door	Locking mechanism – rotating lock	Requires rotation of the wrist supination
1.2.4	Explain the process		
1.4	**Craniocaudal view: right breast**		
1.4.1	Check the support table is the correct size for the client		
1.4.1.1	If the support table is the correct size, load the cassette into the support table	Flip the cassette so that the correct surface is facing upwards (labels facing downwards) Move the switch to the side, either using the right thumb or with the palm for the Mickey Mouse switch Slide the cassette into the slot using the left hand	Twisting of the wrist from supine to prone Slight bending to visually locate the front of the film cassette in the film support table The locking mechanism switch requires excessive force, which is applied by the thumb; this causes local impingement on the thumb There is hyperextension of the thumb when pushing the film cassette into the film support table; this force is applied by the thumb while the wrist is deviated
1.4.4.2	If not, change the support table		
1.4.1.3	If not, change the compression paddle		
1.4.1.4	Get the right size cassettes		
1.4.2	Stick the appropriate viewing numbers onto the support table		
1.4.3.2	Adjust the height of the support table	Observe the height of the breast support table in relation to the client's breasts; alter the height accordingly to ensure that the film support will make contact with the breast at the inframammary crease and chest wall Use the foot pedal or switch on the machine	Left foot Left or right hand to operate the height The view of the breast may be obstructed by features of the mammography unit when the mammography practitioner is adjusting the height of the breast support table; this was often observed to result in a slightly stooped posture

1.4.4.1	Position the client in front of the support table	Position the client as close to the front of the breast support table as possible, rotating her slightly so that the side under examination is brought into close proximity with the breast support table Position the client's torso, feet and head	The mammography practitioner places an arm around the client's shoulder; excessive reaching often results when a small mammography practitioner is screening a tall client or if the mammography practitioner is standing at a slight distance from the client
1.4.4.2 1.4.5.1 1.4.5.2 1.4.5.3 1.4.5.4 1.4.5.5	Position the breast		Lift and tug the breast onto the support table (two handed). Pinch grip, with the fingers positioned under the breast with the thumb on top Standing on the left, smooth the breast down with the fingers on the right hand while applying some compression (depress compression foot pedal with left foot)
1.4.5.6 1.4.5.7	Apply compression	Use the foot pedal	Right arm around the client's shoulder Use the left foot to depress the foot pedal to activate final compression View and read the compression level display. This is positioned at the top of the support table just below the compression pedal outlined in red. Owing to its position on this model of the LORAD machine, the display is very difficult for short mammography practitioners to see. Short mammography practitioners have to stretch to increase their height to view the display
1.4.6.1	Move behind the protective screen		
1.4.6.2	Activate the radiation		Use a finger to depress the button. Forearm at right angles to the upper arm. Upright trunk posture
1.4.7	Compression released	Automatic process	
1.4.8	Move back to the client; remove the cassette from the support table	Move the switch to the side Push the cassette out of the slot Pull the cassette out of the support table slot	Move the switch to the side either using the left thumb or, with the Mickey Mouse switch, using the left palm Use the fingers on the right hand to push the cassette from the bottom out of the slot. Grip the exiting cassette from the top with the left hand. Bring the right hand round to grasp the cassette and pull out of the support table slot
1.4.9.1	Insert the cassette into the computer for naming	Flip the cassette so that the correct surface is facing upwards (so that labels now face upwards) Slide the cassette into the slot	
1.4.9.2	Remove the cassette from the slot	Remove the cassette and place on top of the naming machine	

Table 5 Continued

TA task number	Task element	Control/equipment action	Physical action
1.4	**Craniocaudal view: left breast**		
1.4.1.1	Insert a new cassette into the support table	Pick up the new cassette. Flip the cassette so that the correct surface is facing upwards (with the labels facing downwards) Move the switch to the side, either using right thumb or with the palm for the Mickey Mouse switch Slide the cassette into the slot using the left hand	Twisting of the wrist from supine to prone Slight bending to visually locate the front of the film cassette in the film support table The locking mechanism switch requires excessive force, which is applied by the thumb; this causes local impingement on the thumb There is hyperextension of the thumb when pushing the film cassette into the film support table; this force is applied by the thumb while the wrist is deviated
1.4.2	Stick the appropriate viewing numbers onto the support table		
1.4.3.2	Adjust the height of the support table	Use the foot pedal or switch on the machine	Right foot. Left or right hand
1.4.4.1	Position the client	Position the client close to the front of the breast support table, rotating her slightly so that the side under examination is brought into close proximity with the breast support table Position the client's torso, feet and head	The mammography practitioner places an arm around the client's shoulder; excessive reaching often results when a small mammography practitioner is screening a tall client or if the mammography practitioner is standing at a slight distance from the client
1.4.4.2 1.4.5.1 1.4.5.2 1.4.5.3 1.4.5.4 1.4.5.5	Position the breast		Lift and tug the breast onto the support table (two handed). Pinch grip, with the fingers positioned under breast with the thumb on top Standing on the right, smooth the breast down with the fingers on the right hand while applying some compression (depress compression foot pedal with the left foot)

1.4.5.6 1.4.5.7	Apply compression	Use the foot pedal	Left arm around the client’s shoulder Use the right foot to depress the foot pedal to activate final compression View and read the compression level display. This is positioned at the top of the support table just below the compression pedal outlined in red. Owing to its position on this model of the LORAD machine, the display is very difficult for short mammography practitioners to see. Short mammography practitioners have to stretch to increase their height to view the display
1.4.6.1	Move behind the protective screen		
1.4.6.2	Activate the radiation		Use a finger to depress the button. Forearm at right angles to the upper arm. Upright trunk posture
1.4.8	Remove the cassette from the support table	Move back to the client Move the switch to the side Push the cassette out of the slot Pull the cassette out of the support table slot	Move the switch to the side either using the thumb or, with the Mickey Mouse switch, using the left palm Use the fingers on the right hand to push the cassette out of the slot. Grip the exiting cassette with the left hand. Bring the right hand round to grasp the cassette and pull it out of the support table slot
1.4.9.1	Insert the cassette into the naming machine	Flip the cassette so that the correct surface is facing upwards (so that the labels now face upwards) Slide the cassette into the slot	
1.4.9.2	Remove the cassette from the naming machine and stack on top of the naming machine If the centre has only one size of cassette (the smaller size), REPEAT for larger breasts (if the total breast is not captured on one cassette)	Pull the cassette out of the slot Stack on the machine with the labels facing up	

Table 5 Continued

TA task number	Task element	Control/equipment action	Physical action
1.4	**Mediolateral view: left breast**		
1.4.1.1	Insert a new cassette	Pick up the new cassette Flip the cassette so that the correct surface is facing upwards (labels facing downwards) Move the switch to the side either using the right thumb or the palm for the Mickey Mouse switch Slide the cassette into the slot using the left hand	Twisting of the wrist from supination to pronation Forces applied by the thumb. Some impingement on the thumb
1.4.2	Label the support table with the correct viewing angle label		
1.4.3.1	Adjust the rotation	The switch is located on the rear of the machine arm/head or at the top of the arm/head	Left or right hand
1.4.3.2	Readjust the height if required	Switch on the machine	Left or right hand
1.4.4.1	Position the client and move her arm; ensure her stomach and other breast are not protruding into view		Position the client's left arm to hold the left handle on the machine Mammography practitioners use their arms and body to twist and bend the client to lean sideways over to the left to assist in positioning of the breast

1.4.4.2 1.4.5.1 1.4.5.2 1.4.5.3 1.4.5.4 1.4.5.5	Position the breast	Lifts and cups the breast. If the client is small, then the mammography practitioner may have to stoop to adequately grasp the breast If standing behind the client, the mammography practitioner may not be able to obtain a good view of the breast over the client's shoulder and so will have to twist or bend accordingly When the breast is cupped, the thumb is often hyperextended and the wrist is in extreme ulnar deviation (if the palm is used) Positions the breast on the breast support table to ensure that the nipple is appropriately positioned and the outer quadrant of the breast is brought into contact with the breast support table. Ensures that there are no artefacts or skin folds May have to bend to observe the breast, depending on the height of both the mammography practitioner and the client Stretching of the arm at the maximum range of motion across the breast support table in order to reach the position of the breast Both legs bent and positioned apart to lower overall body position. This posture enables the mammography practitioner to view the breast, which otherwise would be obscured by the head of the machine The neck is extended to view the breast. Both arms are outstretched with the upper arm at 90 degrees to the torso One hand is used to lift the breast The right hand thumb is fully extended and is used to support the weight of breast and to push the breast up to the correct position on the support table. Use of the thumb allows the forearm and wrist to stay in line. However, the thumb is used in a weak position (fully extended) to take the full weight of the breast. The use of the thumb in this posture with such a load places the thumb and wrist at risk of injury, particularly with the rate of repetition and duration of this posture An alternative technique is to use the fingers to support and push the breast into position. This requires the elbow to be held outwards to rotate the forearm so that the palm of the right hand is able to push up against the breast. This will lead to awkward rotation of the shoulder and elbow joints The other hand is used to keep the shoulder, stomach and other breast from protruding into the field of view for imaging Some mammography practitioners are starting to conduct this part of the task while seated

Table 5 Continued

TA task number	Task element	Control/equipment action	Physical action
1.4.5.6 1.4.5.7	Apply compression		Visually locate the pedal; may need to twist to observe the pedal Use the right foot to depress the foot pedal to activate compression. This is conducted while supporting and smoothing the left breast to maintain its correct position on the support table. Once some compression has been applied (sufficient to hold the breast in place), the mammography practitioner removes her hand and applies full compression View and read the compression level display. This is made slightly easier than in the caudal view as the display is rotated; therefore the angles used provide a better view of the display for all statures of mammography practitioner Combined use of the foot pedal and the hand to maintain the position of the breast often results in asymmetrical posture as the body weight is carried by the other foot (non-operating foot). In addition, this leg remains bent with the trunk slightly stooped and the neck is kept extended to maintain a view of the breast during the final compression Activation of the pedal places unequal distribution of the weight on one leg, causing static loading of that leg and an unstable slightly asymmetrical posture
1.4.6.1	Move behind the protective screen		
1.4.6.2	Activate the radiation		Use the finger to depress the button. Forearm at right angles to the upper arm. Upright trunk posture
1.4.8	Remove the cassette from the support table	Move the switch to the side Push the cassette out of the slot Pull the cassette out of the support table slot	Move the switch to the side either using the thumb or, with the Mickey Mouse switch, using the left palm Use fingers on the right hand to push the cassette out of the slot. Grip the exiting cassette with the left hand. Bring the right hand round to grasp the cassette and pull it out of the support table slot
1.4.9.1	Insert the cassette into the naming machine	Flip the cassette so that the correct surface is facing upwards (so that labels now face upwards) Slide the cassette into the slot	
1.4.9.2	Remove the cassette from the naming machine and stack on top of the naming machine	Pull the cassette out of the slot Stack on the machine with the labels facing up	

	If the centre has only one size of cassette (the smaller size), REPEAT for larger breasts (if total breast is not captured on one cassette)		
1.4	**Mediolateral view: right breast**		
1.4.1.1	Insert a new cassette	Pick up the new cassette Flip the cassette so that the correct surface is facing upwards (labels facing downwards) Move the switch to the side either using the right thumb or the palm for the Mickey Mouse switch Slide the cassette into the slot using the left hand	Twisting of the wrist from supination to pronation Forces applied by the thumb. Some impingement on the thumb
1.4.2	Label the support table with the correct viewing angle label		
1.4.3.1	Rotate the arm	The switch is located on the rear of the machine head/arm or at the top of head/arm	Left or right hand
1.4.3.2	Adjust the height	Use the foot pedal or switch on the machine	Left foot Left or right hand
1.4.4.1	Position the client		Position the client's right arm to hold the left handle on the machine. Using arms and body, the mammography practitioner twists and bends the client to lean sideways over to the right to assist in positioning of the breast
1.4.3.1	Readjust the height if required	Use the foot pedal or switch on the machine	Left foot Left or right hand
1.4.3.2	Readjust the rotation if required	The switch is located on the rear of the machine head/arm or at the top of head/arm	Left or right hand
1.4.4.1	Position the client and move her arm; ensure her stomach and other breast are not protruding into view		Ask the client to place her right hand on her head and then position the client's right arm to hold the handle on the machine. Mammography practitioners use their arms and body to twist and bend the client over to the right side to assist in positioning of the breast

Table 5 Continued

TA task number	Task element	Control/equipment action	Physical action
1.4.5.1 1.4.5.2 1.4.5.3 1.4.5.4 1.4.5.5	Position the breast		Lifts and cups the breast. If the client is small, the mammography practitioner may have to stoop to adequately grasp the breast If standing behind the client, the mammography practitioner may not be able to obtain a good view of the breast over the client's shoulder and so will have to twist or bend accordingly When the breast is cupped, the thumb is often hyperextended and the wrist is in extreme ulnar deviation (if the palm is used) Positions the breast on the breast support table to ensure that the nipple is appropriately positioned and the outer quadrant of the breast is brought into contact with the breast support table. Ensures that there are no artefacts or skin folds May have to bend to observe the breast, depending on the height of both the mammography practitioner and the client Stretching of the arm at the maximum range of motion across the breast support table in order to reach the position of the breast Both legs bent and positioned apart to lower overall body position. This posture enables the mammography practitioner to view the breast, which otherwise would be obscured by the head of the machine The neck is extended to view the breast. Both arms are outstretched with the upper arm at 90 degrees to the torso One hand is used to lift the breast The left hand thumb is fully extended and is used to support the weight of breast and to push the breast up to the correct position on the support table. Use of the thumb allows the forearm and wrist to stay in line. However, the thumb is used in a weak position (fully extended) to take the full weight of the breast. The use of the thumb in this posture with such a load places the thumb and wrist at risk of injury, particularly with the rate of repetition and duration of this posture An alternative technique is to use the fingers to support and push the breast into position. This requires the elbow to be held outwards to rotate the forearm so that the palm of the right hand is able to push up against the breast. This will lead to awkward rotation of the shoulder and elbow joints The other hand is used to keep the shoulder, stomach and other breast from protruding into the field of view for imaging

1.4.5.6 1.4.5.7	Apply compression		Use the left foot to depress the foot pedal to activate compression. This is conducted while supporting and smoothing the right breast to maintain its correct position on the support table. Once some compression has been applied (sufficient to hold the breast in place), the mammography practitioner removes her hand and applies full compression using the foot pedal View and read the compression level display. This is made slightly easier than in the caudal view as the display is rotated; therefore the angles used provide a better view of the display for all statures of mammography practitioner Combined use of the foot pedal and the hands to maintain the position of the breast often results in asymmetrical posture as the mammography practitioner's weight is carried by the other foot (non-operating foot); this is nearly a one footed stance as the other foot is used to delicately activate and control the compression pedal. In addition, this leg remains bent with the trunk slightly stooped and the neck is kept extended to maintain a view of the breast during the final compression Activation of the pedal places an unequal distribution of weight on one leg, causing static loading of that leg and an unstable slightly asymmetrical posture
1.4.6.1	Move behind the protective screen		
1.4.6.2	Activate the radiation		Use a finger to depress the button. Forearm at right angles to the upper arm. Upright trunk posture
1.4.8	Remove the cassette from the support table	Move the switch to the side Push the cassette out of the slot Pull the cassette out of the support table slot	Move the switch to side either using one thumb or, with the Mickey Mouse switch, using the left palm Use the fingers on the right hand to push the cassette out of the slot. Grip the exiting cassette with the left hand. Bring the right hand round to grasp the cassette and pull out of the support table slot Pressure applied to release the cassette, often with the finger or thumb extended
1.4.9.1	Insert the cassette into the naming machine	Flip the cassette so that the correct surface is facing upwards (so that the labels now face upwards) Slide the cassette into the slot	
1.4.9.2	Remove the cassette from the naming machine and stack on top of the naming machine	Pull out of the slot Stack on the machine with labels facing up	

Table 5 Continued

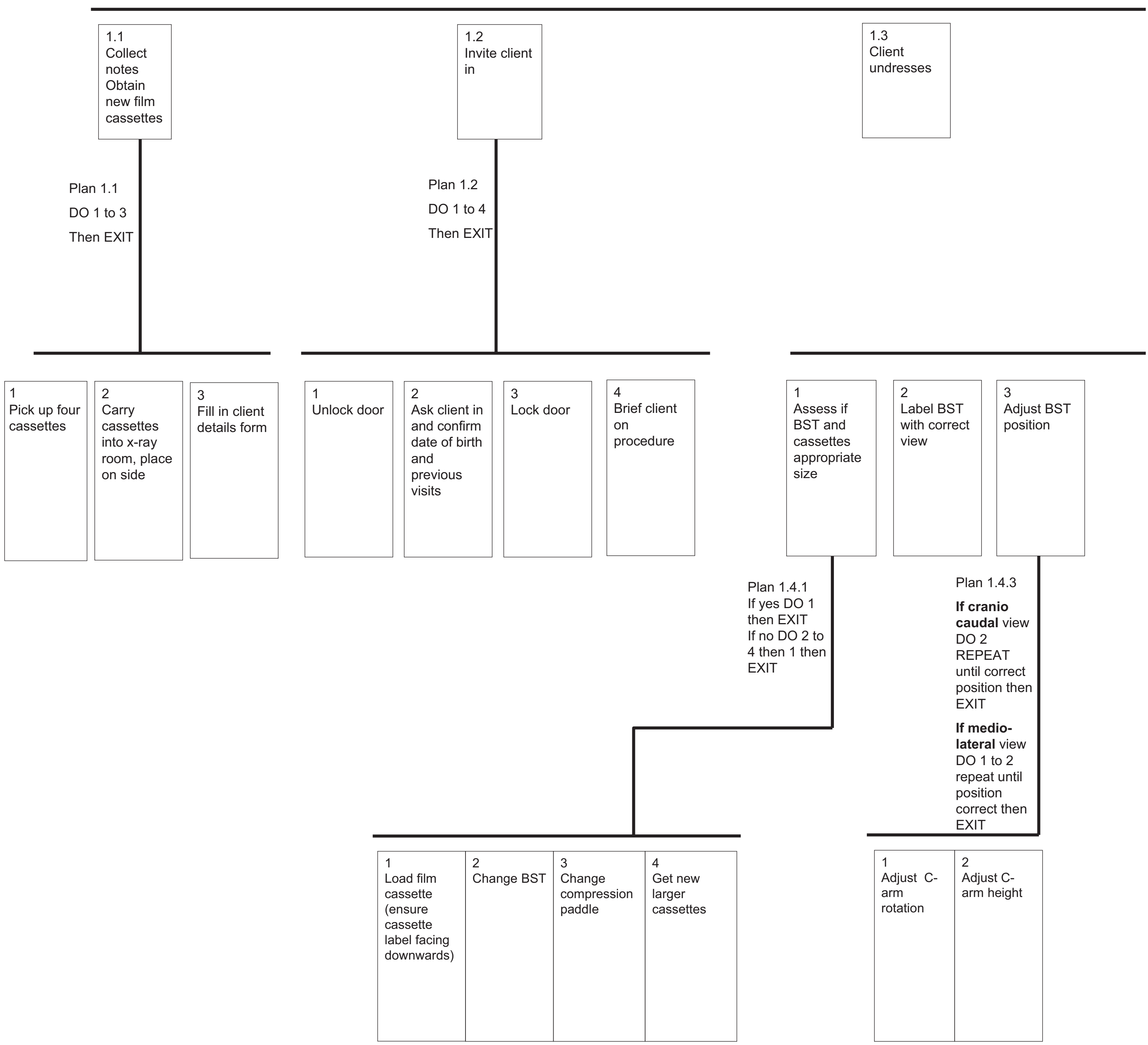
TA task number	Task element	Control/equipment action	Physical action
	If the centre has only one size of cassette (the smaller cassette size), REPEAT for larger breasts (if the total breast cannot be captured on one cassette)		
1.6.1	Ensure the patient returns to the changing room		
1.6.2	Lock the door		
1.7	Clean the machine	Return to the machine	
1.8	Carry completed cassettes out for processing		

Table 6 Task elements and actions involved in film processing

TA task number	Task element	Control/equipment action	Physical action
	Load completed cassettes into the processor		Rotate the cassette so that labels are facing downwards Insert into the processor When it beeps, remove the empty cassette and add to the stack of empty cassettes Repeat for all completed cassettes
	Retrieve the developed films from the other end of the processor		
	Mount the films for checking		
	If the images are poor, retake x-ray films	Repeat all	
	Stick on barcode labels		
	Place into the file for mounting		

APPENDIX 2: TASK ANALYSIS CHARTS

Chart 1 Analogue breast screening system (1)



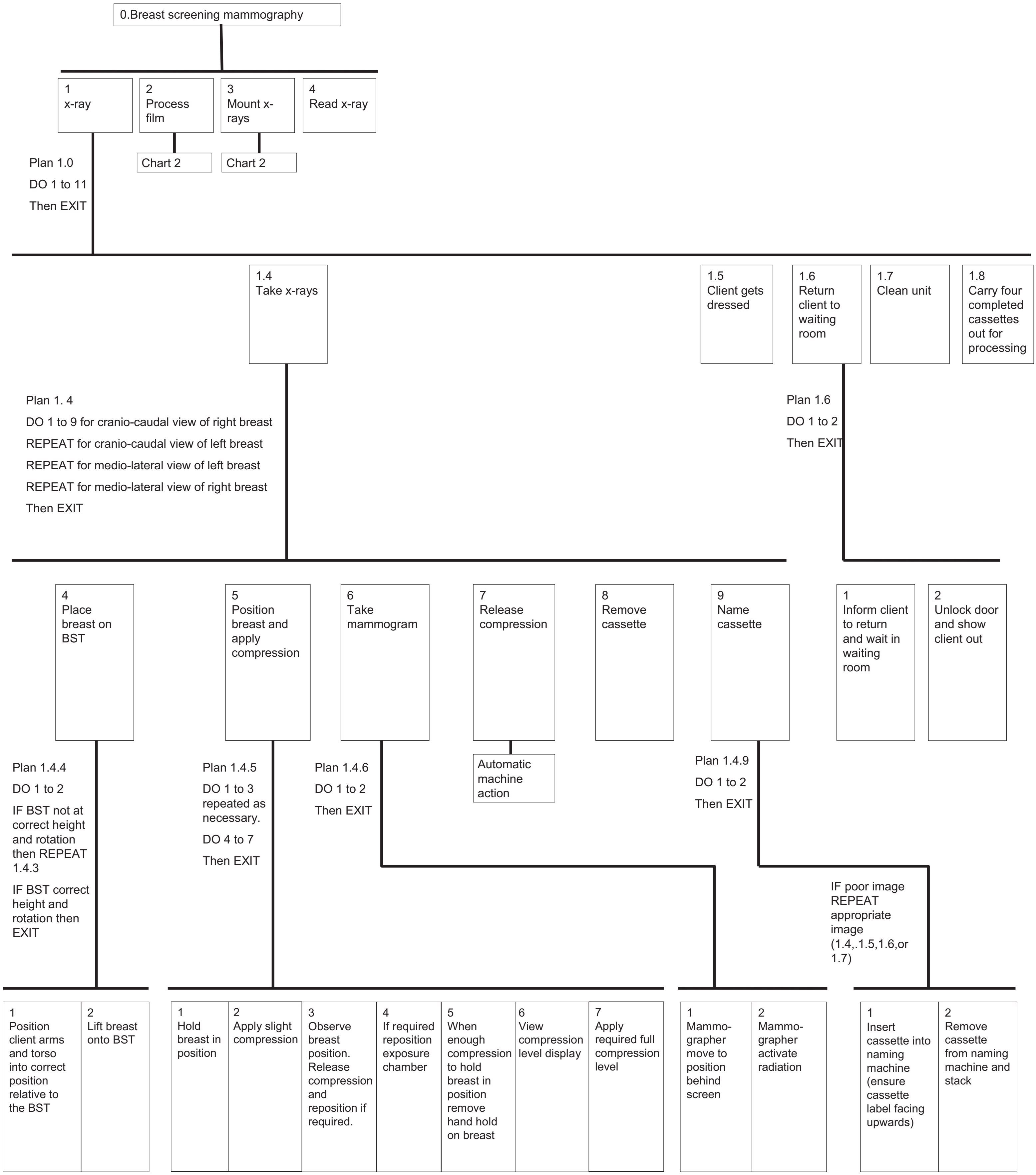
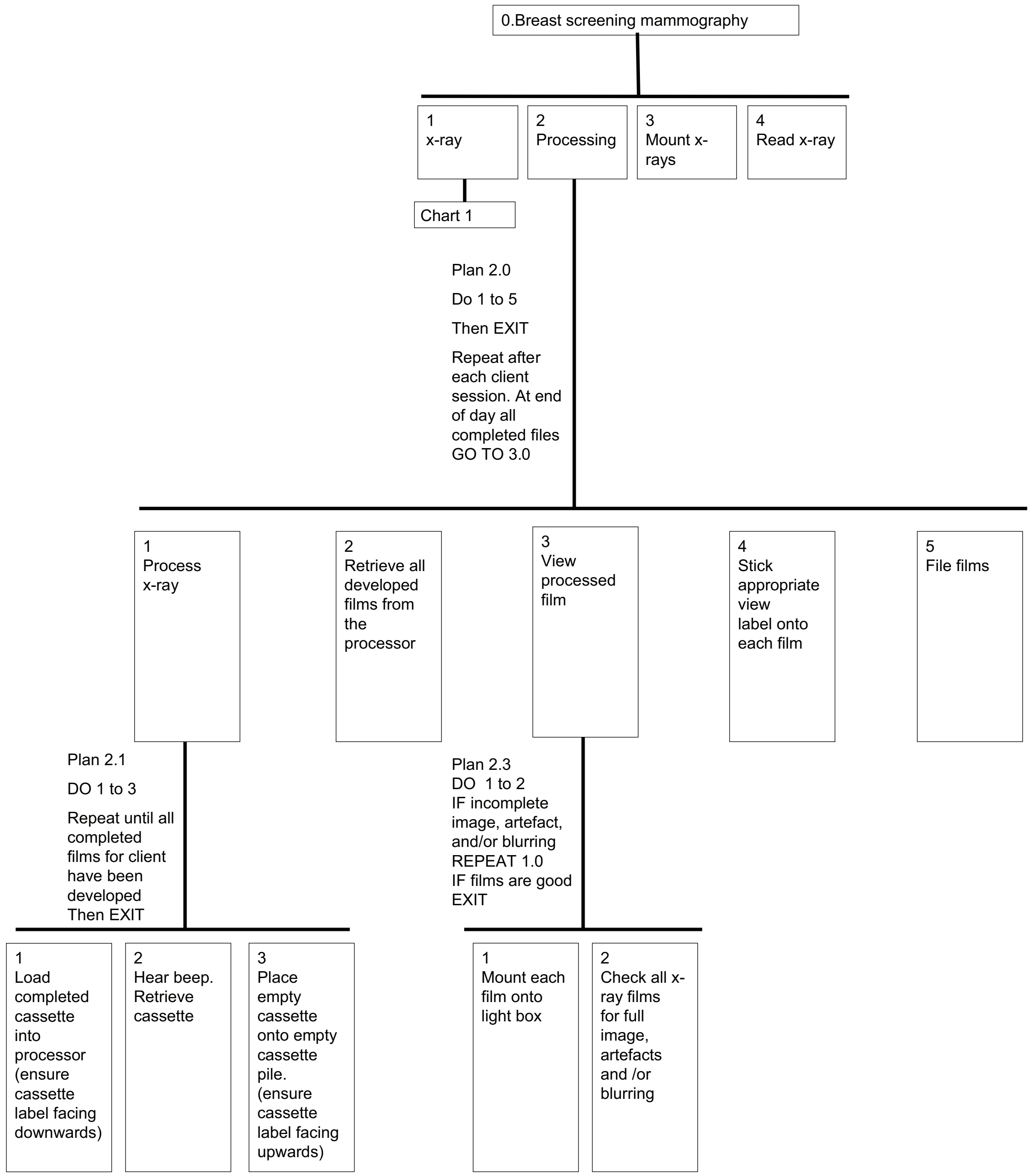

0.Breast screening mammography
1 x-ray
2 Process film
3 Mount x-rays
4 Read x-ray
Chart 2
Chart 2
Plan 1.0
DO 1 to 11
Then EXIT
1.4 Take x-rays
1.5 Client gets dressed
1.6 Return client to waiting room
1.7 Clean unit
1.8 Carry four completed cassettes out for processing
Plan 1. 4
DO 1 to 9 for cranio-caudal view of right breast
REPEAT for cranio-caudal view of left breast
REPEAT for medio-lateral view of left breast
REPEAT for medio-lateral view of right breast
Then EXIT
Plan 1.6
DO 1 to 2
Then EXIT
4 Place breast on BST
5 Position breast and apply compression
6 Take mammogram
7 Release compression
8 Remove cassette
9 Name cassette
1 Inform client to return and wait in waiting room
2 Unlock door and show client out
Automatic machine action
Plan 1.4.4
DO 1 to 2
IF BST not at correct height and rotation then REPEAT 1.4.3
IF BST correct height and rotation then EXIT
Plan 1.4.5
DO 1 to 3 repeated as necessary.
DO 4 to 7
Then EXIT
Plan 1.4.6
DO 1 to 2
Then EXIT
Plan 1.4.9
DO 1 to 2
Then EXIT
IF poor image REPEAT appropriate image (1.4,.1.5,1.6,or 1.7)
1 Position client arms and torso into correct position relative to the BST
2 Lift breast onto BST
1 Hold breast in position
2 Apply slight compression
3 Observe breast position. Release compression and reposition if required.
4 If required reposition exposure chamber
5 When enough compression to hold breast in position remove hand hold on breast
6 View compression level display
7 Apply required full compression level
1 Mammo-grapher move to position behind screen
2 Mammo-grapher activate radiation
1 Insert cassette into naming machine (ensure cassette label facing upwards)
2 Remove cassette from naming machine and stack

Chart 2 Analogue breast screening system (2)



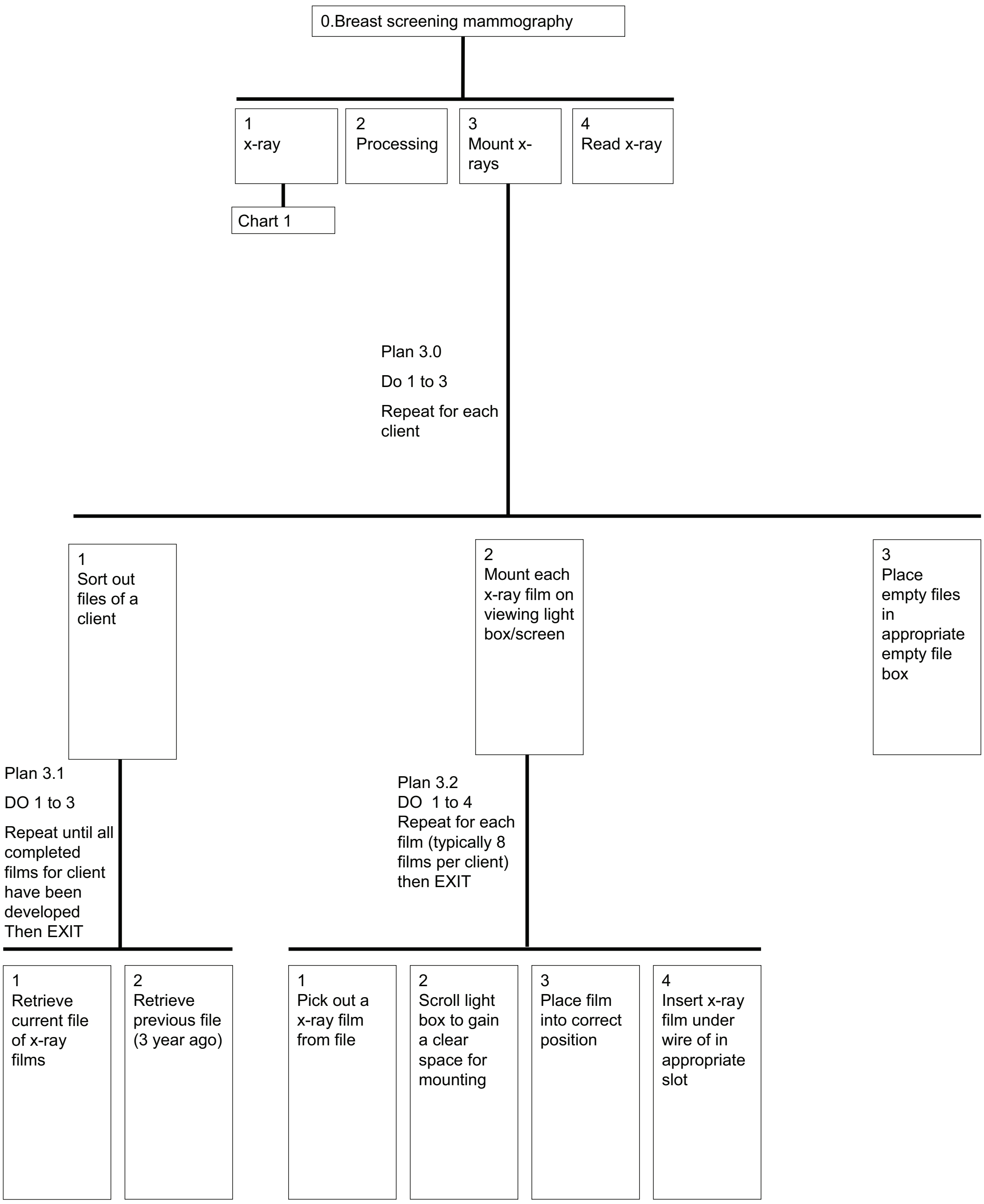
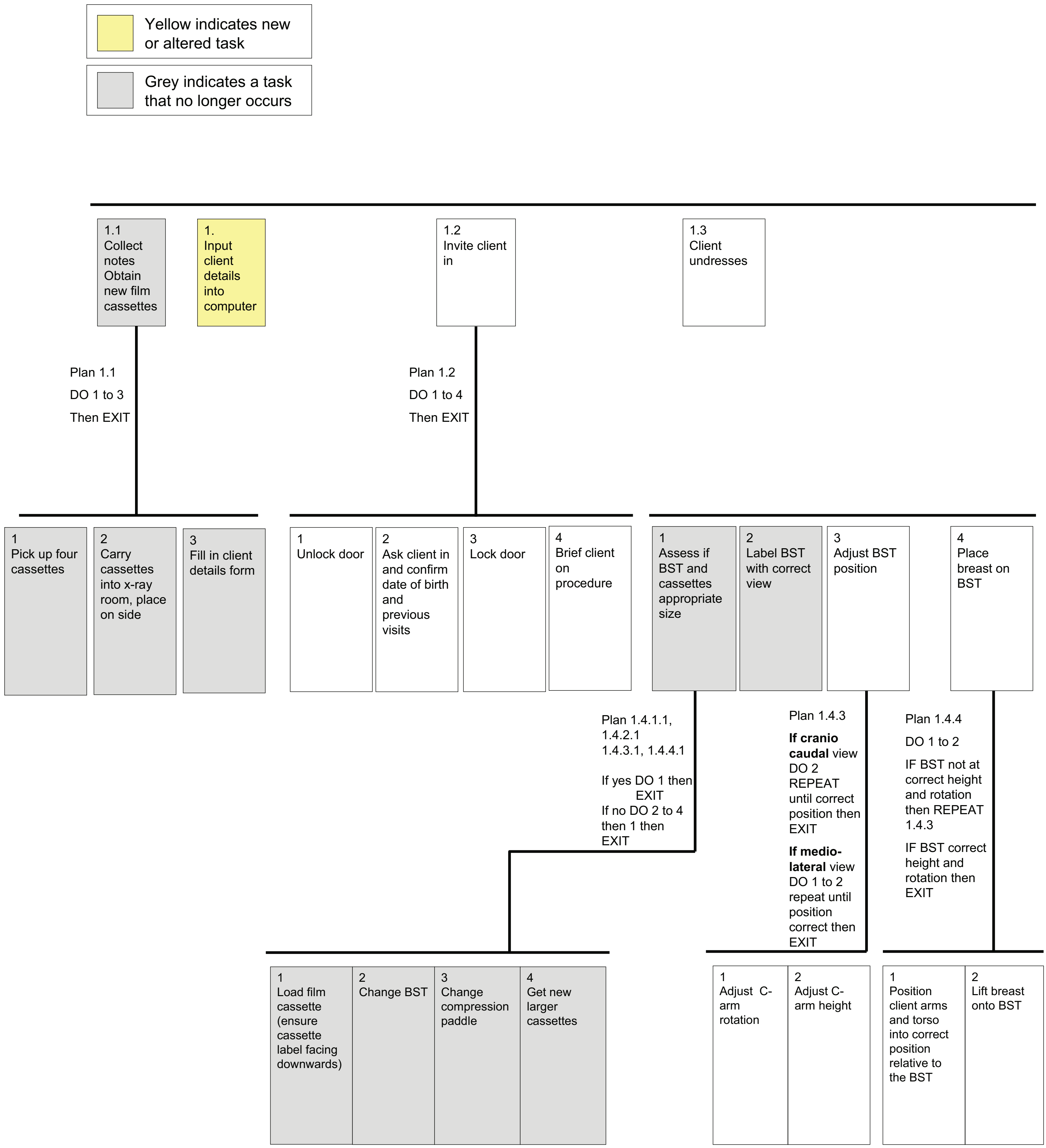

0.Breast screening mammography
1
x-ray
2
Processing
3
Mount x-rays
4
Read x-ray
Chart 1
Plan 3.0
Do 1 to 3
Repeat for each client
1
Sort out files of a client
2
Mount each x-ray film on viewing light box/screen
3
Place empty files in appropriate empty file box
Plan 3.1
DO 1 to 3
Repeat until all completed films for client have been developed
Then EXIT
Plan 3.2
DO 1 to 4
Repeat for each film (typically 8 films per client) then EXIT
1
Retrieve current file of x-ray films
2
Retrieve previous file (3 year ago)
1
Pick out a x-ray film from file
2
Scroll light box to gain a clear space for mounting
3
Place film into correct position
4
Insert x-ray film under wire of in appropriate slot

Chart 3 Digital breast screening system (1)



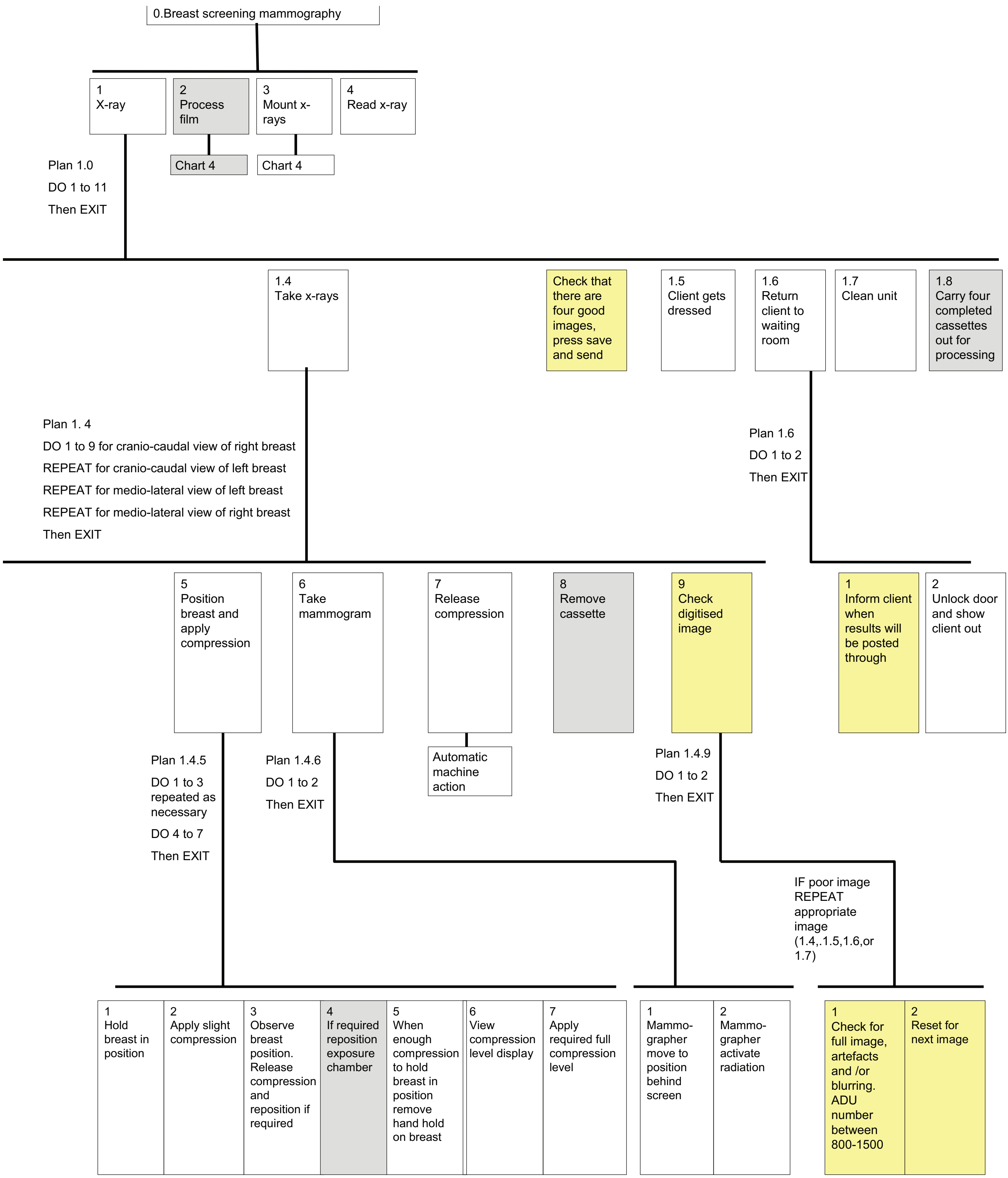
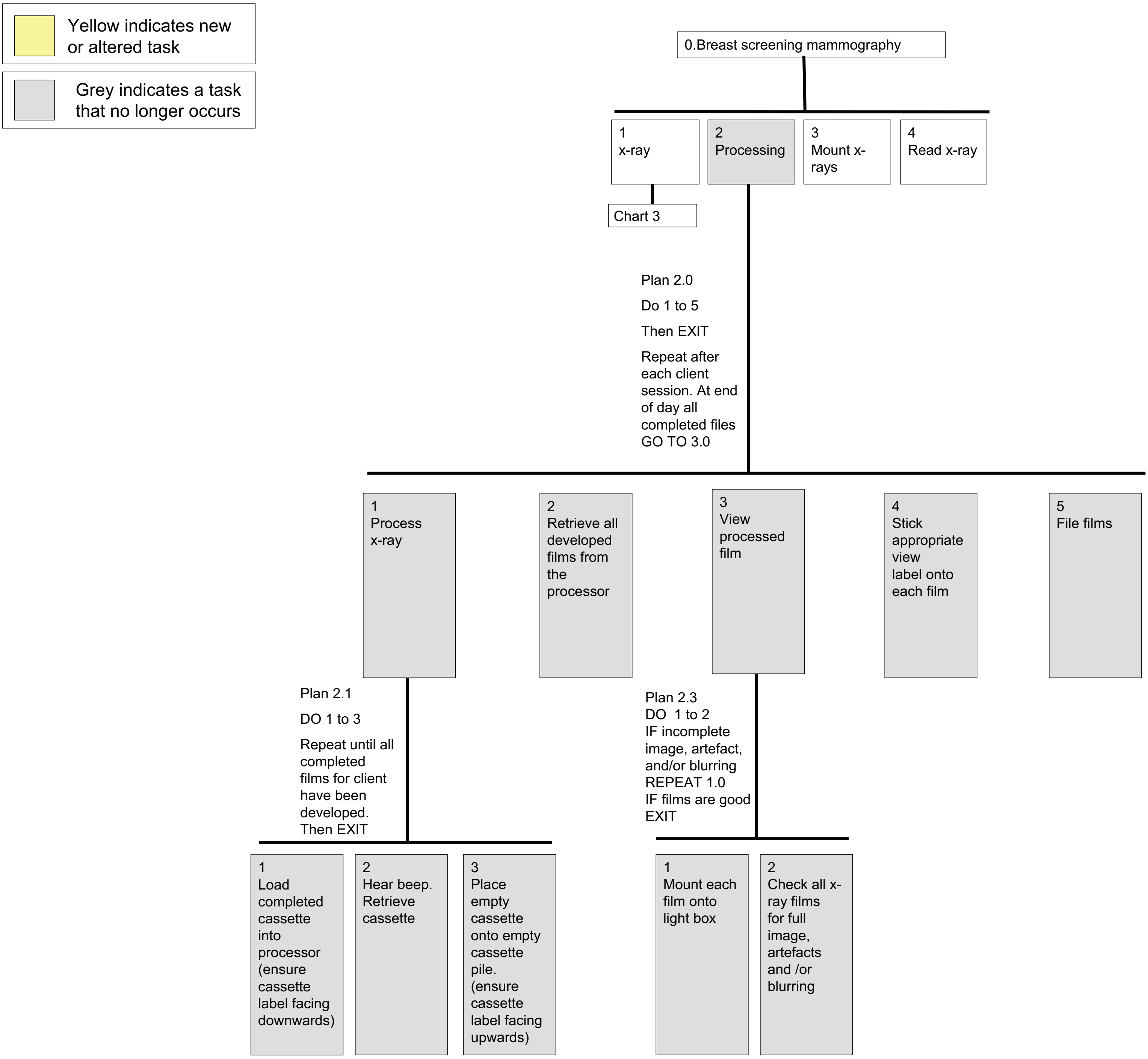

0.Breast screening mammography
1 X-ray
2 Process film
3 Mount x-rays
4 Read x-ray
Chart 4
Chart 4
Plan 1.0
DO 1 to 11
Then EXIT
1.4 Take x-rays
Check that there are four good images, press save and send
1.5 Client gets dressed
1.6 Return client to waiting room
1.7 Clean unit
1.8 Carry four completed cassettes out for processing
Plan 1. 4
DO 1 to 9 for cranio-caudal view of right breast
REPEAT for cranio-caudal view of left breast
REPEAT for medio-lateral view of left breast
REPEAT for medio-lateral view of right breast
Then EXIT
Plan 1.6
DO 1 to 2
Then EXIT
5 Position breast and apply compression
6 Take mammogram
7 Release compression
8 Remove cassette
9 Check digitised image
1 Inform client when results will be posted through
2 Unlock door and show client out
Automatic machine action
Plan 1.4.5
DO 1 to 3 repeated as necessary
DO 4 to 7
Then EXIT
Plan 1.4.6
DO 1 to 2
Then EXIT
Plan 1.4.9
DO 1 to 2
Then EXIT
IF poor image REPEAT appropriate image (1.4,.1.5,1.6,or 1.7)
1 Hold breast in position
2 Apply slight compression
3 Observe breast position. Release compression and reposition if required
4 If required reposition exposure chamber
5 When enough compression to hold breast in position remove hand hold on breast
6 View compression level display
7 Apply required full compression level
1 Mammo-grapher move to position behind screen
2 Mammo-grapher activate radiation
1 Check for full image, artefacts and /or blurring. ADU number between 800-1500
2 Reset for next image

Chart 4 Digital breast screening system (2)



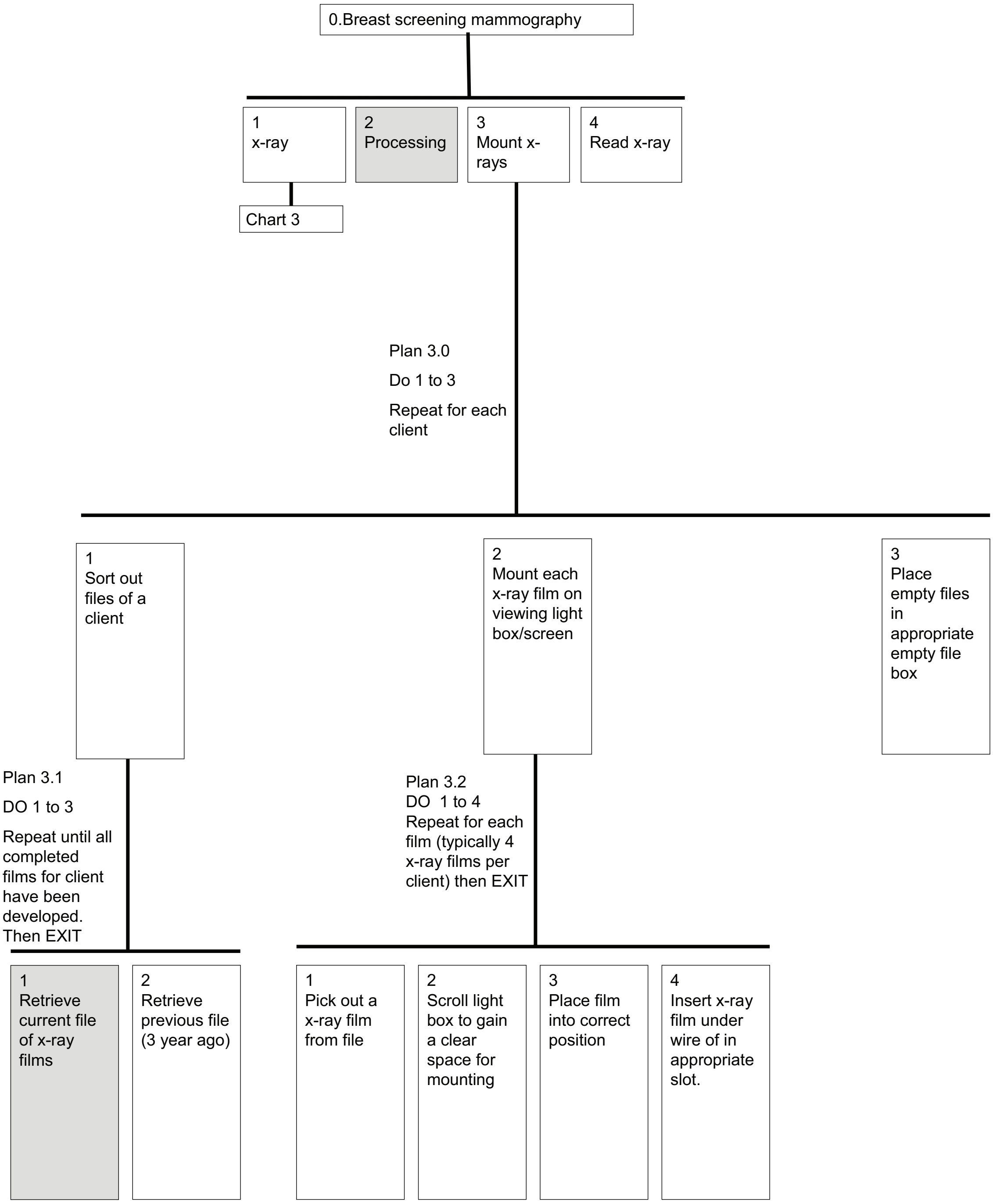
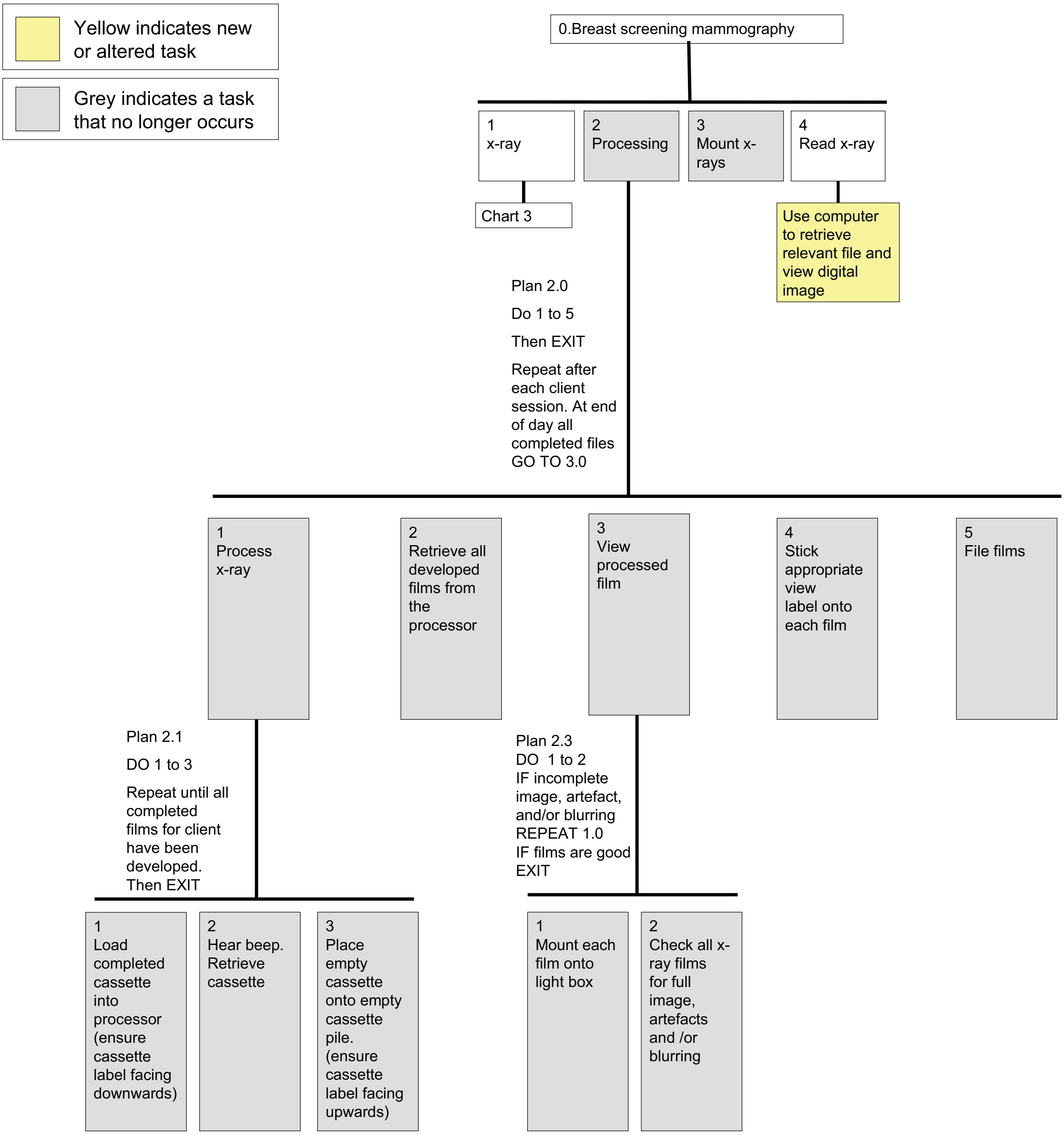
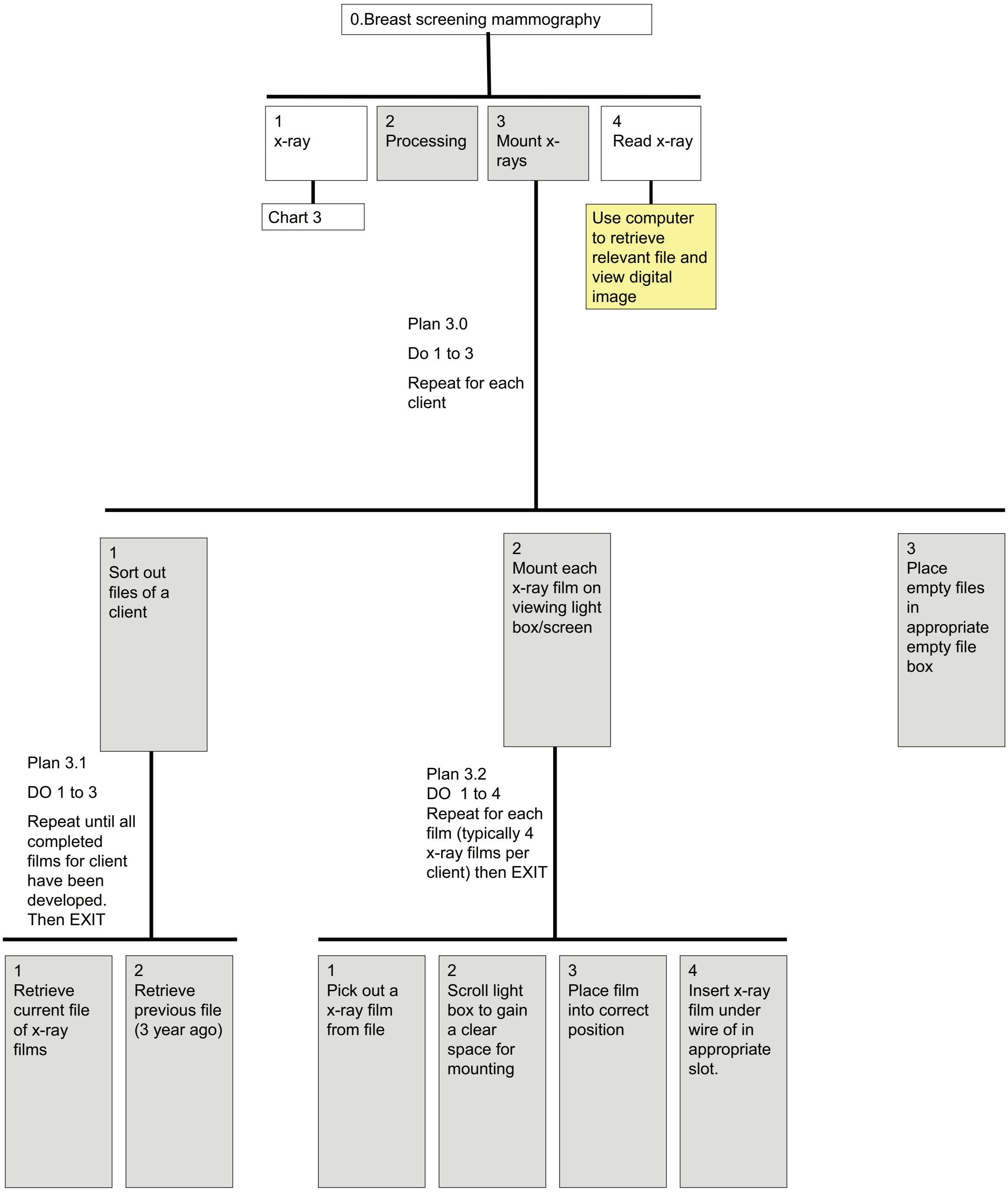

0.Breast screening mammography
1 x-ray
2 Processing
3 Mount x-rays
4 Read x-ray
Chart 3
Plan 3.0
Do 1 to 3
Repeat for each client
1 Sort out files of a client
2 Mount each x-ray film on viewing light box/screen
3 Place empty files in appropriate empty file box
Plan 3.1
DO 1 to 3
Repeat until all completed films for client have been developed. Then EXIT
Plan 3.2
DO 1 to 4
Repeat for each film (typically 4 x-ray films per client) then EXIT
1 Retrieve current file of x-ray films
2 Retrieve previous file (3 year ago)
1 Pick out a x-ray film from file
2 Scroll light box to gain a clear space for mounting
3 Place film into correct position
4 Insert x-ray film under wire of in appropriate slot.

Chart 5 Digital breast screening system

(when all previous images are digital)




0.Breast screening mammography
1 x-ray
2 Processing
3 Mount x-rays
4 Read x-ray
Chart 3
Use computer to retrieve relevant file and view digital image
Plan 3.0
Do 1 to 3
Repeat for each client
1 Sort out files of a client
2 Mount each x-ray film on viewing light box/screen
3 Place empty files in appropriate empty file box
Plan 3.1
DO 1 to 3
Repeat until all completed films for client have been developed. Then EXIT
Plan 3.2
DO 1 to 4
Repeat for each film (typically 4 x-ray films per client) then EXIT
1 Retrieve current file of x-ray films
2 Retrieve previous file (3 year ago)
1 Pick out a x-ray film from file
2 Scroll light box to gain a clear space for mounting
3 Place film into correct position
4 Insert x-ray film under wire of in appropriate slot.