

Digitisation of analogue screening mammograms

Norwegian Breast Cancer Screening Program Troms and Finnmark



Reference:

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Abstract:

In the coming years a transition from analogue to digital imaging technology will take place in the Norwegian Breast Cancer Screening Program (NBCSP). This will make softcopy reading of images possible. However, one will also wish to compare new (digital) images with prior images on film. This can be solved in different ways. This report contains a brief description of different alternatives. The solution chosen in Troms and Finnmark, digitisation of prior images, is then described in detail. Both technical and economical aspects are covered.

Referanse:

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Emneord:

Mammografi. Mammografiscreening. Digital mammografi. Digitalisering av mammogrammer.

Resymé:

I Mammografiprogrammet vil det i de nærmest årene skje en overgang fra analog til digital avbildningsteknikk. Dette muliggjør granskning av bilder på skjerm. Samtidig vil man ønske å sammenlikne nye (digitale) bilder med gamle bilder som fins på film. Dette kan løses på flere måter. I denne rapporten skisseres kort ulike løsningsalternativer. Videre beskrives i detalj hvordan man i Mammografiprogrammet i Troms og Finnmark har valgt å løse dette ved å digitalisere gamle bilder. Både tekniske løsninger og økonomiske forhold beskrives.

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Approved:



Gunnar Saxebøl, director, Department for Radiation Protection and Nuclear safety.

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PREFACE

From February 2004 the Norwegian Breast Cancer Screening Program (NBCSP) offers regular mammography screening examinations to all Norwegian women between 50 and 69 years of age. This means that a little over 460 000 women are covered by the programme. Until now mainly analogue technique, in which the images are read and stored on film, has been used. However, a transition from analogue to digital technique is currently taking place also in mammography. One consequence is that the image information becomes digital and may be read on a monitor (softcopy reading).

When the screening mammograms are being read it is common to use prior images as reference. The transitional phase between analogue and digital technique will therefore represent a challenge in screening because the prior and current images inherently exist in different formats (on film and electronic, respectively). All sites that have screened with analogue technique must decide how to handle this challenge.

In the NBCSP Troms and Finnmark one expects to perform some screening with digital technique from the second half of 2004. In preparation for this, one has chosen to digitise analogue images from prior screening rounds so that both prior and current images will be available in the same format (electronic). This will allow for softcopy reading of both prior and current images. Technical and economical aspects related to the first phase of this work are described in this report.

Reidar Kind at the Centre for Economy and Analysis, UNN, contributed to chapter 2.6.

Jan Husebye at the Cancer Registry contributed to chapter 2.6.1.

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1 Introduction

1.1 Background

The Norwegian Breast Cancer Screening Program (NBCSP) started as a trial project in four counties in 1995. After the inclusion of Vestfold County in February 2004, the programme covers the entire country. Vestfold will use only digital imaging equipment from the start of their screening activity. All images from the Breast Centre in Tønsberg will thus be in digital format. In Oslo, screening with both analogue and digital systems has been conducted since 2000. Consequently, a portion of the screening images in Oslo is in digital format. At all the other screening centres, all image information is in analogue format (i.e., on film).

A gradual transition from analogue to digital imaging equipment is expected in the NBCSP. For well-established screening counties the trend is that they wish to have digital equipment installed at the assessment lab(s) while continuing for the foreseeable future with analogue equipment for the screening examination.

1.2 Challenges in the transition period between analogue and digital technique

Digital images can in principle be read in two different formats:

1. Printed on film ("hard copy")
2. Displayed on an electronic display device ("soft copy")

Some of the advantages of digital images (for example interactive adjustment of display parameters, communication, archiving) disappears if the hardcopy format is chosen. In the long term it is therefore expected that radiologists will wish to read digital images on softcopy.

When reading screening images, one wishes to detect small changes in the breasts. One method being used to achieve this is to continuously compare new images with images from prior examinations. If prior screening images are available, these are preferred. Alternatively, images from other examinations can be used.

When an established screening operation moves from analogue to digital imaging technology also for the screening examination, there will be a transitional phase when the new screening images are in digital format while the prior images are in analogue format (film). There are several ways to solve this, all with their advantages and disadvantages (these are not discussed in further detail here):

-
- 1) All new, digital screening images are printed on film. The routines for handling and reading films remain unchanged. The transition to softcopy reading only takes place when (at least) one digital screening examination exists for all/most women who has been screened previously.
 - 2) New, digital screening images are softcopy read
 - a) Without prior images. For instance, films might routinely be made available at the consensus conference or on demand.
 - b) With prior films displayed on light boxes in close proximity.
 - c) With digitised versions of prior films made available on the review workstation.

1.3 Preparation for transition to digital screening in Troms and Finnmark

The Breast Diagnostic Centre covering Troms and Finnmark counties is located at the University hospital of North Norway (UNN) in Tromsø. At this location there are two mammography laboratories, one for screening and one for assessment. In addition, a mobile unit is used. Approximately 75% of the screening examinations are performed at the mobile unit.

Full digitisation of the centre is planned. The process of installation of digital equipment started in December 2002, when the assessment lab was partially digitised (both film and CR plates can be used). Further plans include making both labs at the centre completely digital within the second quarter of 2004 and the mobile unit as soon as possible after this.

NBCSP in Troms and Finnmark started in spring 2000. By summer 2004, two screening rounds will have been conducted. Round three will commence when screening starts after the summer break.

In NBCSP Troms and Finnmark it is deemed essential to compare new and prior images at screening. Digital images are planned read on softcopy. For the transition period between analogue and digital technique one was therefore left with alternatives 2)b) and 2)c) from section 1.2. Alternative c) (digitisation of priors) was deemed the best choice for the screening situation, consequently this is currently in the process of being realised. The details of this process are described in this report.

2 Digitisation of images from prior screening examinations

2.1 Demographic data, film archive, and digital storage medium (PACS)

NBCSP Troms and Finnmark covers a population of approximately 23 500 women. All the women's demographic data, their screening attendance and the result(s) of the screening examination(s), are stored in a central database at the Cancer Registry. Each invitation for each woman is identified with a unique invitation number, which is a central sorting key.

The image information (the films) is stored locally in a film archive. The examinations are sorted according to birth day – month – year so that it starts with women born 1 January and ends with women born 31 December. Screening – and assessment examinations for the women are stored together. The archive is located at UNN at the same level as the Breast Diagnostic Centre, and a couple of minutes' walk from the Centre.

At UNN there is a PACS from Agfa (Impax 4.5). It has been decided to archive even digital (screening-) mammograms in the hospital PACS. The stipulated volume of digitised images is around 400 Gbyte.

2.2 Digitisation of images

NBCSP Troms and Finnmark has, through its participation in the SCREEN TRIAL project (<http://www.mevis.de/projects/screen-trial/index.html>), acquired the unit M5000-DM (EU) from R2 Technology, Inc. This unit consists of a digitiser (scanner) and a module for CAD processing of images (digitised or original digital). The scanner is a modified version of the Canon CFS300, capable of delivering a spatial resolution of 50 μm . This resolution is necessary if R2 CAD processing on digitised images is to be carried out. At UNN it was decided that CAD processing was not required for prior (digitised) images. The images are therefore digitised at 100 μm spatial resolution. Compared to a digitisation with higher spatial resolution this significantly reduces the volume of stored image data.

The scanner has a stack loader with a capacity of 100 sheets. This will normally be equivalent to 20 examinations with four images and one separator sheet.

In the digitisation process the scanner performs a linear transformation from optical density (OD) in the film to pixel values. The greyscale resolution is 12 bit. The linear transformation does not give an optimal softcopy presentation. In order to achieve this, an (optimised) look up

table (LUT) is needed. Currently, such a table is under development but has not yet been implemented. This work must be finalised before the images are needed in routine screening.

Pixel data is sent from the scanner to a separate module where it is merged with patient information. The “products” sent from this module, are correctly labelled DICOM images.

2.3 Which images are digitised?

Demographic data is stored in the central database at the Cancer Registry while the digital images are to go into the hospital PACS. Consequently, there was a need to merge data from these two data sources. However, for a variety of reasons a direct (digital) coupling was not feasible. Therefore, in October 2003, necessary data pertaining to women who had attended the screening programme in Troms and Finnmark up to a specific date was extracted from the central database. Approximate cost of this operation is given in Table 1.

To start with, the following is digitised:

- The screening examination of
 1. All women who attended the first screening round (= first “woman” and “county round”) 2000-2002
 2. All women who were invited to the first screening round (“county round”) 2000-2002 and did not attend, but who attended in the second “county round” (2002 2004).
 3. All women who were invited to screening for the first time in “county round” number two and who attended.

After the first and major digitisation effort, digitised screening images for a total of about 19815 women reside in the PACS. The images of women screened for the first time after the data extraction date will be digitised when “county round” number two is finished in spring 2004.

A standard examination consists of four mammograms: one CC and one MLO image for each breast. Exceptions:

- In some cases more than one image per projection has been made in order to cover the entire breast completely. These are digitised according to a mosaic procedure developed by R2 in which the images are given a DICOM label that informs the display system about the order in which the images are to be displayed.
- For women who have had a mastectomy an extra lateral projection has been made. This extra image is NOT digitised.
- For women who have reported feeling a lump, an extra image has been made. This extra image is NOT digitised.

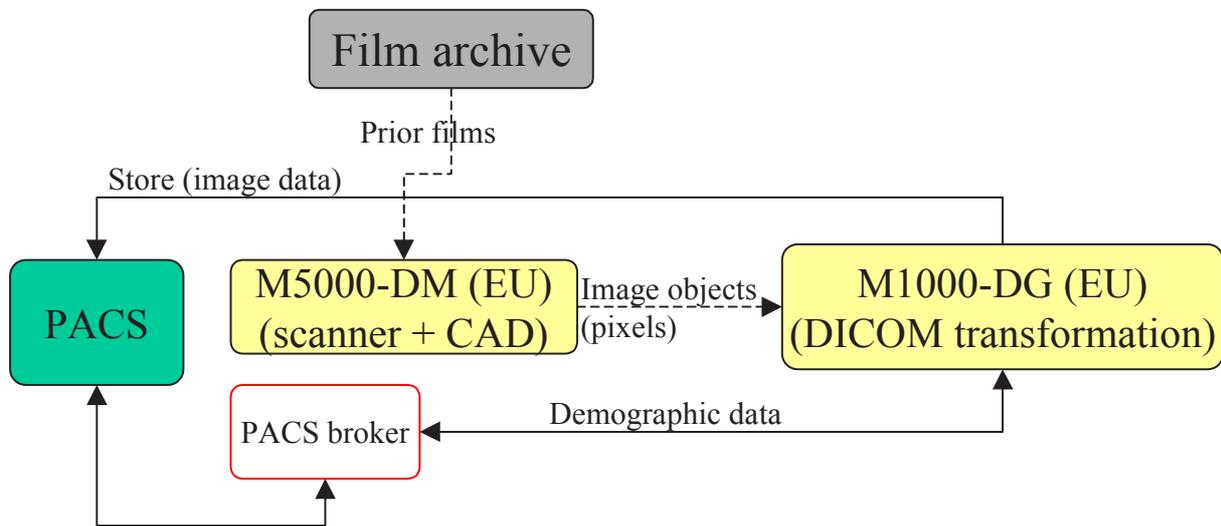
2.4 Coupling of demographic and image data

For each woman the extracted demographic data contains the following information:

- Data and time of the examination
- Birth date and unique identification number
- Last and first name
- Invitation number
- Mammography lab

The demographic data is made available to a supplementary system, M1000-DG (EU), (R2 Image Checker DICOM Gateway) via a so-called PACS broker, and the coupling of demographic data and image data takes place here (see even 2.2).

2.4.1 Diagram showing the data flow



2.4.2 Transfer of demographic data to the PACS broker

The Cancer Registry put the demographic information in a file with one row for each woman. In addition, they developed software that generates two files for each woman, using the original file as input data. These files have file extensions .dat and .sig. The .dat files are text files containing the necessary information about the women in a format that the PACS broker can read. The .sig files only exist for control reasons. The broker will only read the .dat files provided it finds a file with the same name and the file extension .sig.

Due to a limit on capacity, the total volume of files must be made available to the PACS broker in smaller batches. In practice a computer engineer has generated .dat and .sig files in batches of 2000, i.e., for 1000 women at a time. These files have then been copied manually to the input folder of the broker where they are read. 2000 files would take up the entire broker capacity for approximately 1,5 hours and block other registrations. The number of files copied at a time has therefore been limited to between 100 and 200.

When this operation was finished it was discovered that approximately 450 examinations were not found in the original input file. The main reasons for this was later found to be

- The examination was performed after the date the data was extracted from the database. Data for the examination consequently did not exist in the original data. This was known in advance.
- The data existed in the file but was sorted incorrectly and not found by the search procedure.
- The women had attended screening more than once. Data from the second attendance was extracted (while images from the first attendance were to be digitised).

- Some examinations were registered with a wrong unit code (lab).
- Data from a few examinations fit the extraction criteria but were still not extracted.
- Data from a few examinations existed in the original extracted data in correct format but were still not found by the search procedure. The reason(s) for this is unknown.

The data for these examinations had to be written into text files manually.

2.4.3 Contents of files sent to the PACS broker

Format:

StudyScheduled/<date> <time>/	date=YYYYMMDD time = HHMMSS
0010,0020/<Birth date> <personal ID number>/	
0010,0010/<Last name> <First name>/	
0010,0050/<Birth date>/	Birth date = DDMMYYYY
0010,1000/<Personal ID number>/	
0008,0050/<Prefix><Accession number>/	23.<invitation number>
0033,1000/<Imaging date>/	imaging date = DDMMYYYY
0040,0010/<lab>	

Example:

StudyScheduled/19052002 085926/
0010,0020/111111 11111/
0010,0010/Normann Kari/
0010,0050/11111111/
0010,1000/11111/
0008,0050/23.1102335/
0033,1000/19052002/
0040,0010/22/

2.4.4 Merging data from the DICOM gateway and the PACS broker

Using the Invitation Number (in DICOM terms, Accession Number attribute) as the matching key, R2 has implemented two DICOM options to query for the patient and screening round information:

1. Modality Worklist Information Model – FIND and
2. Study Root Query/Retrieve Information Model – FIND.

For either query model, R2 provides the following DICOM attributes in the C-FIND request:

- Patient ID: zero length
- Patient's Name: zero length
- Patient's Birth Date: zero length
- Patient's sex: zero length
- Accession Number: Invitation Number (barcode read by M-1000 DG)
- Referring Physician's Name: zero length
- Study Instance UID: zero length

The remaining attributes are represented differently in the two query models. For Modality Worklist, the following attributes are also included in the C-FIND request:

- Scheduled Procedure Step Sequence (one sequence Item, as follows):
 - Scheduled Procedure Step Start Date: zero length (returned value is Study Date)
 - Scheduled Procedure Step Start Time: zero length (returned value is Study Time)

For Study Root, the following attributes are also included in the C-FIND request:

- Study ID: zero length
- Study Date: zero length
- Study Time: zero length

The attributes that are sent with zero length value in the C-FIND request are expected to be returned with the actual value in a matching C-FIND response. However, the R2 system will be satisfied with zero length value in the matching response for all attributes except the Patient ID and Patient's Name. If a Study Instance UID is not provided, the R2 system will create one for the DICOM image objects. The rest of the attributes will remain zero length in the DICOM image object, unless the person using the system provides the information by manual data entry.

The user may enter the following information manually, if the query response does not provide it:

- Patient ID
- Patient's Name
- Patient's Birth Date
- Patient's Sex
- Accession Number

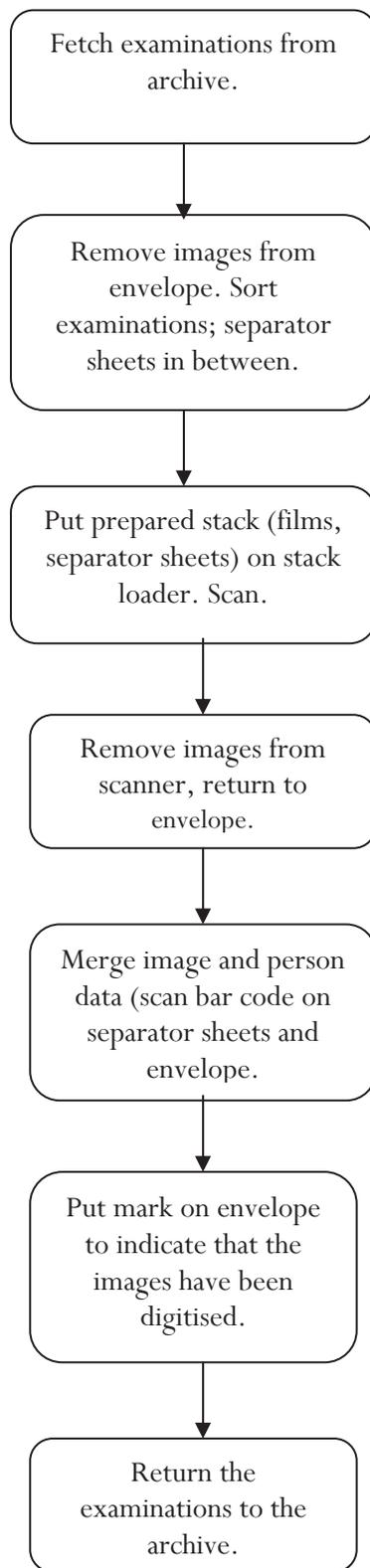
-
- Study Date
 - Study Time

In the digitisation procedure at UNN, the study root query model has been utilised. A query with Accession Number (send C-FIND request with Accession Number (here: invitation number) as parameter) returns the woman's name, ID and examination date (C-FIND response). This information is put in the DICOM header of the digitised images, which are then sent to the PACS.

2.5 Digitisation in practice

At UNN, one person has been employed full time to handle image digitisation only. This person has to some extent received assistance from other personnel at the unit regarding fetching and archiving films.

The main steps in the process are shown schematically below:



For films of format 18 cm x 24 cm the scanning procedure takes about 52-53 minutes per 100 sheets. This equals 20 examinations (four standard images and one separator sheet per examination). If a few examinations of format 24 cm x 30 cm are included, the scanning time is prolonged by a couple of minutes. Estimated time for the process outlined above is 1,5 hours.

2.5.1 Problems and solutions

Mostly the digitisation process has been carried out without major incidents. Some minor problems have been connected to the specific systems in use (data flow, user interface etc.) and will not be described in detail.

When it comes to problems that are more general in character, the following should be mentioned:

- In some instances the digitised examinations were not automatically sent to the PACS. A preliminary counting shows a discrepancy between the number of examinations registered as digitised at the digitisation unit and the number found in the PACS of about 4,7%.
- In some instances an error message, saying that DICOM transformation was not performed, was displayed.

It was difficult or impossible to identify these examinations because the images at this stage only have an internal identity code connected to the corresponding separator sheet. When the examination is put back into the envelope, this connection does no longer exist.

For women who have attended two screening rounds the procedures states that the first examination is to be digitised.

- As mentioned in section 2.4.2, demographic data was missing for approximately 450 examinations. It turned out that for some of these, demographic data from their second screening attendance had been used.
- In some cases the first examination was incomplete (for example, one image was missing). If the second examination was complete, this was digitised. For these cases, the information regarding the date and time of the examination is incorrect.

It has been observed that on occasion a strip of extra ID stickers (stickers on a paper background) has been put in the envelope. In some cases the stickers begin to loosen from the paper background and instead get attached to the films and/or leave traces of glue. This can be unfortunate if the glue gets into the scanner.

2.6 Costs

The original aim of the digitisation project was to provide access to digitised versions of prior screening images for close to all women who had attended a screening examination at least once. During the planning phase it was believed that all screening examinations in Troms and Finnmark would be performed with digital image acquisition equipment from the fall of 2004. It was therefore originally thought that only archived screening mammograms would be digitised and that this process would take place within a limited period of time. During and after the project period, additional factors pointing to a continual need for some image digitisation even in the future have come to light. This is described in more detail in the sections below.

2.6.1 Delays in the transition to digital screening equipment

From August 2004 the stationary screening lab and the clinical lab at the breast diagnostic centre will be equipped with digital image acquisition systems. At the mobile screening unit film will still be used. These analogue screening images will be read on film as they have been in the past. However, digitisation of the mammograms from two specific groups of women examined at the mobile unit will be needed:

1. Women who attend the screening programme for the first time. This is in order to provide digital screening mammograms of these women when they attend in the next round.
2. Women who are recalled from the mobile unit. This is because the images acquired at assessment will be digital and soft copy read. One would like to have both the screening and assessment images of these women available in the same format (digital).

It is not yet known when digital equipment will be installed at the mobile unit. In the following it is assumed that installation will happen during the summer of 2005, which will be half way through the screening round. For group 1 this means: In the screening round starting in August 2004 (county round number three), about 23400 women will be invited to mammography screening in Troms and Finnmark, approximately 3000 are invited for the first time. Of these 3000, 1100 will be invited to the mobile unit during the fall of 2004 and the spring of 2005. With an estimated attendance rate of 83%, this translates into 913 first time attendees showing up for screening at the mobile unit by the summer of 2005. For group 2, the following is taken into account: A total of about 9100 women will be invited to the mobile unit in the fall of 2004 and spring of 2005. 8000 of these (9100 minus 1100 first time attendees) have been invited before. With an estimated attendance rate of 83% this translates into 6640 examinations. With a predicted recall rate of 4%, the number of examinations that needs to be digitised will be 265. In total from group 1 and 2, the estimated number of examinations that will have to be digitised is 1178.

2.6.2 Clinical patients

At the Breast Diagnostic Centre in Tromsø a number of patient referred from outside the screening programme is also examined. For some of these there will be prior (analogue) images available, either in the local archive or from other sources. Because the new images for these women will be digital, and one wishes to soft copy read all images, prior images of these patients will also be digitised. Based on numbers from prior years it is estimated that the number of such examinations will be approximately 1500 the second year and 1000 the third year. (The first year is here taken to mean the fall of 2003 and the spring of 2004).

By combining the numbers from sections 2.6.1 and 2.6.2 one arrives at a total digitisation need of 2678 examinations the second year and 1000 examinations the third year.

2.6.3 Investments and costs related to the digitisation of analogue screening images

The costs fall into two categories: costs of hardware and cost of work. It has been summarised in the table below. All costs are given in Norwegian kroner (NOK). Since the equipment was bought specifically for this project, a model including depreciation has not been used.

With the exception of the buying price of the equipment and the costs related to digitisation of the images from the screening archive in the spring of 2004, all numbers are based on estimates rather than verified costs. The table therefore mainly gives a realistic impression of what types of costs and activities have and will be associated with the digitisation project at UNN.

Table 1

What	Who	Time	Applied unit price	1st year	2nd year	3rd year	Total, three years
Scanning equipment and installation ¹⁾			-	337100			337100
Service			-		Not yet known	Not yet known	Not yet known
Extraction of demographic data from the Cancer Registry database	Computer engineers, Cancer Registry	1,5 day	1400/day	1400	700	0	2100
Programming of Java-application	Computer engineers, Cancer Registry	1 day	1400/day	1400	0	0	1400
Installation, start-up	IT personnel, UNN	2 days	1500/day	3000	0	0	3000
File handling	IT personnel, UNN	2,5 days	1400/day	1400	1400	700	3500
Image handling, scanning (archived images, 1st year)	External consultant	-	Fixed amount per scanned examination + travel expenses	275800	0	0	275800
Manual registration of 450 cases		Approx. 20 hours	200/hour	4000	0	0	4000
Image handling, scanning (1st year) ²⁾	Personnel at Breast Diagnostic Centre	23 hours	200/hour	4600	0	0	4600
Image handling, scanning (2nd year) ³⁾	Personnel at Breast Diagnostic Centre	200 hours	200/hour	0	40000	0	40000
Image handling,	Personnel at Breast	75 hours		0	0	15000	15000

scanning (3rd year) ⁴⁾	Diagnostic Centre						
Total number of examinations				20265	2678	1000	23943
Total cost							686500
Cost per examination							28,7

¹⁾The equipment was bought from the USA. Total price: USD 46830. An exchange rate of 7,19967 has been used.

²⁾The number of hours has been calculated the following way: 450 examinations/(20 examinations scanned per hour)=22,5 hours. The number is rounded to 23 hours.

³⁾The number of hours has been calculated the following way: Number of examinations/(20 examinations scanned per hour) x 1,5. The factor 1,5 is used to take into account fetching and archiving of examinations and the need to manually register patient data. The total number of hours is then 2678 examinations/(20 examination per hour) x 1,5=200,85 hours. The number is rounded to 200 hours.

⁴⁾The number of hours has been calculated the following way: Number of examinations / (20 examinations per hour) x 1,5. The factor 1,5 is used to take into account fetching and archiving of examinations and the need to manually register patient data. The total number of hours is then 1000 examinations/(20 examinations per hour) x 1,5=75 hours.

⁵⁾The number of examinations for the first year was calculated after the major operation of digitising the archived images was finished. At the digitisation unit a total count of 20795 digitised examinations was registered. A search in the PACS identified the examinations of 19815 women. 450 women whose examinations were not found in the PACS were also identified. Demographic data for these women was registered manually and the images digitised. The total number amounted to 19815+450=20265 examinations.

2.7 Summary

In this report we have described the main points in the digitisation of prior screening mammograms at UNN. The report includes work done prior to digital screening. A simplifying factor has been that one has not had to select specific examinations (for example because these will be needed in the near future), but has been able to work one's way through the archive successively from beginning to end.

In the simple cost analysis some assumptions regarding the further use of the equipment the next couple of years have been made.

Since digital screening is not yet done at UNN, we can not report any practical experience in using the digitised priors. We also have to defer descriptions of solutions for the period in which screening is probably done with digital equipment at one lab (stationary) and with analogue equipment at the other (mobile).

The process of digitising images has been carried out with only minor problems. The cost per examination is estimated at NOK 28,7.

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